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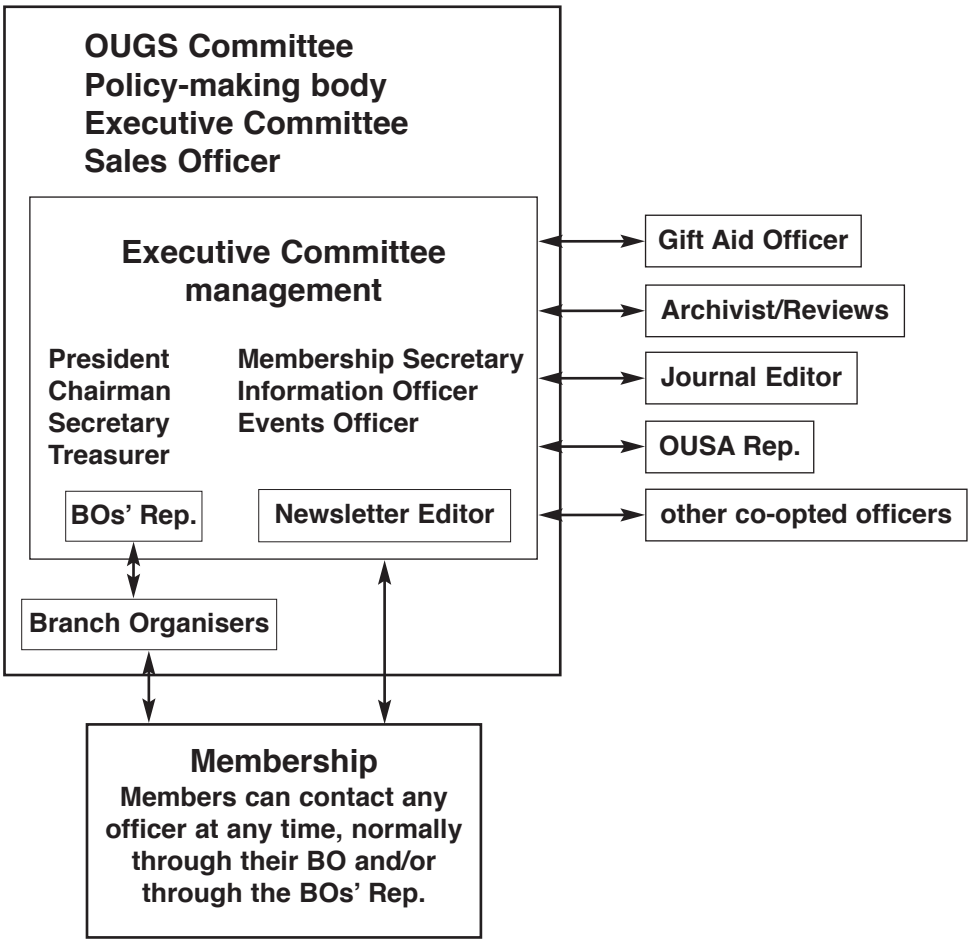

Editorial:

Dear readers,

This issue of the OUGSJ *comprises papers and abstracts from the OUGS Symposium at Northampton University, 17–19 August 2012, a celebration of the OUGS's 40th Anniversary as a geological society.*

The Symposium's theme was 'Earth Sciences at [The] OU and the OUGS', so the Friday evening opening keynote address by Prof. Chris Wilson was, appropriately, on the foundation and early development of The OU's Earth Sciences Department and its courses. Chris was not only a founding Lecturer in The OU, but also our second OUGS President, after Ian Gass, founder and Professor of the Department.

There were 10 lectures delivered over the symposium weekend, covering topics from The OU's foundation through current OU staff research in all aspects of geology and palaeontology, both by current members of staff and by retired staff who have been active throughout the OUGS's existence, many of them former OUGS presidents through the years. Unfortunately, five of these speakers were unable to write up their lectures as papers for the OUGSJ*, so we are able to include only their abstracts. In one case an originally scheduled speaker, Prof. Tony Grindrod, was unfortunately held up in an airport abroad and therefore unable to make it to the Symposium. Fortunately, however, Prof. Grindrod was able to come to the April 2013 OUGS AGM and deliver his lecture at that event, so we hope to publish his paper on 'The Earth's physical resources at The Open University' in* OUGSJ *34 (2).*

Also to our good fortune, the dynamic Dr Jill Eyers — whose long-time association with The OU and with the OUGS is well known — was prepared to step in and present a talk on Geoconservation in Buckinghamshire. I'd like to add that Jill was my OU Summer School Tutor at Durham when I was studying S236 [as then was], and the enthusiasm with which Jill lead us on our field trips and in the lab sessions inspired me to continue studying and complete my OU BSc in Earth Sciences.

I also remember that Dr Peter Skelton, who also presented a paper at this Symposium, was also a Tutor at that year's S236 Summer School. I remember at one of those informal chats after dinner, before heading to the labs, he described to a few of us the new course being developed and on offer the next year — S269 Earth and Life. He described it so enthusiastically, in fact, that I resolved then and there to sign up for the course (despite the usual OU perceived 'wisdom' — 'Never take a course in its first year'). Well, I did anyway, and the texts, in the new OU format of 'metric demi-quarto', were all ready and printed on time, were brilliantly written and illustrated in full colour, and a joy to read and study. Full marks for Dr Skelton and his team of authors!

Other aspects of earth sciences presented at this symposium focused on the 'flip-side' of palaeontology — its conservation. The talks by Drs Dee Edwards and Dave Williams showed us how all those fossil kits were provided to us OU students, and how some new techniques in photography reveal details about Archaeopteryx that we never knew.

Mountains and volcanoes have of course always been the bulk and spreading for our geological sandwiches, and talks by Dr Tom Argles and by Prof. Hazel Rymer covered some histories of research about these areas, respectively; and fieldwork, of course, is the preparation, the developing techniques of which, actually and virtually, were discussed by Prof. Nigel Harris.

Two other areas of earth sciences are extraterrestrial geology and how we present ourselves / appear to the public. Regarding the former, Prof. Simon Kelly spoke to us about those big rocks that hurl through space and hit the Earth. To paraphrase his title, they're not just holes in the ground!

Regarding how we earth scientists, amateur and professional alike, present ourselves to the public, we all know how important this aspect of our work is. Dr Dave Rothery, whose research interests embrace both Earth-bound rocks and geological processes, and extraterrestrial geology, has throughout his career been a leader in interacting and advising the public about geology through the media. Explaining to the public what has been going on inside, on the surface of, and beyond the Earth in clear, understandable terms is something at which he has become impressively adept. His dubbing by an Al Jazeera *correspondent as 'Chairman Dept of Natural Disasters' has got to be a first. But then, few can boast of having been recruited for and given a media report and explanation about an earthquake, on a mobile phone while horseback riding.*

How cool is that? 'Ride on', Dr Dave! Now that's what I call 'thinking on the hoof'!

As always, I wish you happy reading.

— David M. Jones, OUGS Journal Editor

OU Earth Sciences: Laying the foundations

Prof. Chris Wilson

Emeritus Professor of Earth Sciences, The Open University
OUGS President 1975–1976 and 2003–2004

Abstract

A personal recollection of the early years of The Open University's development from the perspective of having participated in the production of the first Science Foundation Course and Earth Science courses. Chris Wilson recounts how we had to design a new degree programme, new methods of presentation and assessment, and a new infrastructure to support students studying at home all over the UK. In 1969, colleagues thought that we must be mad to give up secure 'normal' university jobs to join such a speculative venture. I was not long before they had top change their minds.

"The Open University was the first institution in UK higher education to break the insidious link between exclusivity and excellence."[1]

The first Chancellor, Lord Crowther, gave this memorable vision for The OU at the Charter Ceremony held at the Royal Society in 1969:

"... open as to people ... open as to places ... open as to methods ... and open, finally, as to ideas.

This statement encapsulated a revolutionary new idea for the future of higher education and, like all revolutionary ideas, attracted hostility and criticism. The Open University succeeded because all those who participated in its birth and early development — politicians, staff and students — had together an unbeatable combination of foresight, leadership, determination and enthusiasm.

In the summer of 2009 I attended a gathering at Walton Hall of staff recruited in 1969 to celebrate and reminisce about the first 40 years of The Open University. The OUGS 40th Anniversary Symposium gave me another opportunity to reminiscence about the early years of The OU and in particular it's Department of Earth Sciences.

This contribution is a personal recollection and understanding of how The OU and OU Earth Sciences started — it is not meant to be a thorough historical account. I hope it will trigger memories among the first members of the OUGS and give some new insights about the founding of The OU to those students and staff who joined our community in later years.

I will focus on the following topics:

- why I joined The OU
- a political conception: a short history up to 1969
- key political and academic players
- the first two years

Why I joined The OU in 1969

The summer of 1965 was a momentous time in my life. I had finished my PhD, got married and started my first job as a lecturer in geology at what was then Kingston College of Technology (now University). Little did I know that as I started at Kingston the government of the day was planning to launch a new institution that would change the course of my future professional life and that four years later I would join a new controversial and revolutionary venture in higher education.

When I was at Kingston College of Technology students were enrolled on an external University of London geology degree. Not infrequently the final examinations set by the external examiners seemed at best to explore the outer reaches of the curriculum that they had devised or at worst to bear little relation to it. This was very frustrating for both students and teaching staff, but it did have the benefit of making us all determined to work together to 'beat the London examiners'. I learned a lot about undergraduate teaching during my four years at Kingston and concluded that the lecture was not a very effective teaching method. So I devised a number of student-active and self-guided practical sessions. When the opportunity came, therefore, to apply for a job that would involve designing a new undergraduate degree and teaching system from scratch I could not believe my luck. But I wondered whether I would be even more fortunate and be appointed to the fledgling Open University. During the Easter vacation of 1969 I returned from a field trip in south-west England for a successful interview in London at the imposing temporary office of The OU in Belgrave Square. Almost exactly 40 years later my OU career culminated with a gratifying geographical symmetry when I was presented as Emeritus Professor of Earth Sciences at an OU degree ceremony held in Torquay.

A political conception: a short history up to 1969[1, 2]

The use of broadcasting to provide higher education had been around for sometime with an educationalist at the BBC, J. C. Stoddart, suggesting in 1929 a 'wireless university' to Lord Reith in an internal memorandum. This idea finally took off in the early 1960s as this brief list of key events shows:

1962 Michael Young proposed an open university to prepare students for external degrees of London University.
1963 March: Labour party report proposes a university of the air (UoA).
September: Labour commits to UoA.
1964 Labour wins general election (majority of 4).
1965 March: Jennie Lee given responsibility for UoA.
August: Report of the UoA Planning Committee completed (received by Cabinet in February 1966).
1966 Labour re-elected with a majority of 98.
1967 Cabinet sets up Planning Committee to work on a comprehensive plan for an open university.
1968 Walter Perry appointed as The OU's first Vice-Chancellor.
1969 First staff appointed and begin work on foundation courses for first presentation in February 1971.

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I am still amazed that it took less than a decade for the concept of an open university to be formulated and then made a reality. Perhaps it is even more amazing that academic staff only began serious preparatory work when they joined The OU in September 1969 — only 18 months before the launch of the first foundation courses.

Key political and academic players

There is no doubt that The OU was founded on the political will of Prime Minister Harold Wilson and his ministerial colleague Jennie Lee. Together they managed to sidestep the political and educational establishment.

Harold Wilson

In his Foreword to Walter Perry's book[2] documenting the establishment of The OU Harold Wilson wrote:

> The decision to create [T]he Open University, then known as the 'University of the Air', was a political act. It was announced as a firm commitment of the incoming Labour Government on 8 September 1963; the text and outline proposals had been written out by hand in less than an hour after church on the previous Easter Sunday morning. It was never party policy, nor did it feature in Labour's election manifesto. But our political history is full of cases where the Prime Minister has a private hobby-horse and is determined to use the not inconsiderable resources of his office to get it through, whatever the opposition.
>
> That opposition was pretty massive. The original proposals met an almost unanimously hostile press … Opposition in the educational world, from the established universities to adult education and local authorities, was hardly less robust.

Jennie Lee

Harold Wilson appointed Jennie Lee Minister for Arts after the 1964 election. In 1965 he moved her to Minister of Sate in the Department for Education and Science with special responsibility for The Open University. There is a general consensus that without her drive and enthusiasm the project might never have come to fruition. She commented:

> In the Ministry, I was de jure a Minister of State — a junior minister — but de facto I was working on my own, dealing directly with the Treasury and with the Prime Minister. The civil servants hated it: all very irregular. But it was the only way you could get a new job done.[1]

Jennie Lee, and The Open University Planning Committee working with her, rejected the possibility that a consortium of existing universities should organise the new institution or act as external examiner for its degrees. She stated:

> I knew it had to be a university with no concessions, right from the very beginning. I knew the conservatism and vested interests of the academic world. I didn't believe we could get it through if we lowered our standards.[1]

A crucial step in ensuring high standards was to recruit talented and experienced senior members of staff who would plan and guide the early development of The Open University. Comments on three of these follow.

Walter Perry

Walter Perry, later Sir Walter and then Lord Perry, was The Open University's first Vice-Chancellor between 1969 and 1982. Previously he had been Professor of Pharmacology at the University of Edinburgh. He was an "... enlightened educationalist whose toughness, ingenuity and tact launched The Open University."[3]

On the tenth anniversary of the founding of the university Walter Perry reflected on why he applied:

> I had heard about the University of the Air, but I regarded it as a political gimmick unlikely ever to be put into practice. It wasn't until my son read out the advertisement for the post of Vice-Chancellor that I began to think seriously about the proposal and the challenge it presented.
>
> It wasn't that I had any deep-seated urge to mitigate the miseries of the depressed adult; it was that I was persuaded that the standard of teaching in conventional universities was pretty deplorable. It suddenly struck me that if you could use the media and devise course materials that would work for students all by themselves, then inevitably you were bound to affect — for good — the standard of teaching in conventional universities. I believed that to be so important that it overrode almost everything else. And that is what I said in my application.[1]

When he ceased to be Vice-Chancellor there was, as a member of staff put it, "... a strong sense of vacuum."[3]

He died in 2003.

Mike Pentz

Mike Pentz was first Dean of Science between 1969 and 1985. Previously he was a nuclear physicist at CERN and left-wing peace campaigner, continuing with the latter role while at The Open University. He was a larger then life figure both in stature and voice.

> He was one of the first to realise the essentially hybrid nature of [T]he OU (part academic, part industrial) and all the implications of that fact. This was probably because his previous training and experience ... as a physicist and engineer. He understood that planning, scheduling, establishing production norms (however alien they might seem to normal academic life) were essential if the primary aim of [T]he OU — to produce effective, academically viable, distance-learning courses — was to be achieved.[4]

If it had been an Olympic sport, Mike would have won a gold medal in scheduling. He constantly tried to quantify how long it would take to prepare course components despite the fact that most had yet to be written. He antagonised OU arts and social science colleagues by haranguing them at Senate meetings and elsewhere about how much longer it would take to prepare high-quality science courses compared to their teaching materials. He was right — but I would say that wouldn't I?

Mike Pentz died in 1995.

Ian Gass

Ian Gass was the first Head of Earth Sciences between 1969 and 1982. Previously he was Senior Lecturer in Earth Sciences at the

University of Leeds. He was the first person to recognise that the Troodos Mountains in Cyprus are a fragment of ocean crust.

Having a secure academic position and an established research reputation, Ian had a lot to lose by joining The OU at a time when its continuation was in doubt should there be a change in government. Colleagues at Leeds told him The OU would be a 'flash in a pan'. Years later he delighted in telling them that it was "some flash, some pan."

Ian, like his fellow head of department biologist Stephen Rose, would not have joined The OU unless he had been given assurances about the importance of research by Walter Perry. Ian led and built the strongest of the four science departments — we had a real sense of identity compared to the others. In 1987 the department was ranked as one of top seven UK Earth Science research departments by the Earth Sciences Review commissioned by the University Grants Committee.

Ian was elected a Fellow of the Royal Society in 1983 soon after retiring as Head of Department at The OU (although he remained as a professorial staff member).

Sadly he died in 1992 the year after he retired from The OU.

The first three years

The race is on

In the autumn of 1969 a small number of staff set out to build a totally new university system — on an industrial scale and with national coverage — in only 18 months. Perhaps the Planning Committee had set the ambitious start date of February 1971 conscious that that a change of government would result in The OU being strangled soon after it was born. When we started work we were certainly aware that an election was not far off and that the Conservative opposition saw The OU as a flimsy gimmick of the Labour Prime Minister Harold Wilson.

In his book[2] Walter Perry recounts how the Tory Education spokesman, Sir Edward Boyle, was under severe pressure from his backbenchers as soon as the Labour government announced its commitment to the report of The OU Planning Committee in January 1969. Walter Perry Commented that Sir Edward Boyle's speech the next day:

> ... did not say the Conservatives would not support the new venture but, on the other hand, her carefully gave no guarantee that they would … It was probably the mildest attack on The Open University that Sir Edward Boyle felt that he could get away with.[2]

In June 1970 the Conservatives won the General Election with a majority of 31. The new Chancellor of the Exchequer was Ian McLeod, who had a few months earlier stated that The OU was "blithering nonsense". Fortunately before the election Officers of The OU had invited the new Tory spokesperson for Education, Margaret Thatcher, to dinner. Walter Perry commented that it was "a memorable occasion", and that:

> Margaret Thatcher, who is a lawyer by instinct as much as by training, came prepared to attack on all fronts. She suggested first that our main activity would be to offer courses on 'hobbies'. I fear that I needle very easily and this attack got under my skin in no uncertain manner — as she no doubt intended. The exchanges were short, sharp and furious. I am happy to say that, despite it all, we ended on a friendly note. Mrs. Thatcher went away admitting that not only was she much better informed but that, even if she was not yet persuaded of the validity of the whole concept, at least the edge of her criticism had been blunted. When she became Minister for Education after the Tory victory in 1970 we had reason to be glad of that dinner.[2]

The OU survived the change in government, albeit with a reduced budget. By 1976, when he wrote his book about the early history of The OU, Walter Perry was able to say that he felt that the institution was now outside politics and that it had largely achieved this position through its academic success.

Planning the first Science Foundation Course

Dean Pentz got his eight first recruits to the Science Faculty to work even before we formally joined The OU in September 1969. Over the summer of that year we were all asked to read more than 100 proposals, submitted by all the shortlisted candidates, for the content of the Foundation Course in Science . Many did not even mention earth science. The OU's Head of Physics stated that his subject was the only possible foundation!

When we met as a course team we faced a daunting task: design and produce in 18 months a course that had no entry requirements that would prepare students to study university-level science courses. Not surprisingly, we soon decided that the course would provide an introduction to all four of the science disciplines, and that there should be as much inter-disciplinary teaching as possible. Sadly it did not work out that way, save for Ian Gass and Russell Stannard in physics working very well together to use an introduction to the internal structure of the Earth as a vehicle to teach wave theory.

What should the Earth Science components of the Foundation Course cover? Many of the proposals by the shortlisted candidates that we read adopted a conventional approach — rocks, minerals and fossils with a bit of Earth structure and history. Ian Gass and I agreed that the best approach to designing 'our' part of the course was to consider the question: what should students who will take no further earth science courses at The OU know about the Earth when they have finished the Foundation Course? The answer was clear, given that the revolution of plate tectonics had only just happened. We were so lucky to be in the right place at the right time to place this new concept at the heart of the first section of the earth sciences in the course.

We wondered about using *Scientific American*-type articles to compile an Earth Science set book, but could not find enough material at the right level. So we decided to produce a multi-authored text. But could we find authors who would be able and willing to submit chapters in less than six months, and was there a publisher out there willing to produce the book in a further six months, in time for use by students in March 1971? Ian Gass's reputation and contacts largely ensured that we recruited the authors, and with the help of The OU Publishing Department a small publisher was found — Artemis Press — headed by the charismatic Michael Bizony.

And so *Understanding the Earth* was born. It was hugely successful, being used not only by OU undergraduates but also by students in many other UK universities. It was also translated into several other languages. I still have the Japanese version — the only part I can read are the initials of the three editors on the title page! The book put OU Earth Sciences on the map and

contributed considerably to The OU's reputation for producing high-quality teaching materials.

Delivering high quality teaching

As we now know, high-quality teaching has been the key to The OU's success. This was and still is achieved by using course teams to plan and produce material and by having these materials externally assessed. Course outlines were discussed by the course team and also commented on by an external course assessor eminent in his or her field. The drafting of teaching texts went through three stages of course team discussion, with the final version being commented on by a specialist external assessor. The final version was then further improved by OU professional editors who marked up copy to go to the printers. In house graphic artists produced all the figures. Today this process has been streamlined to some extent, but The OU still ensures that far more quality control goes into the preparation of its courses than any conventional university. The latter still rely on their external examiners who at The OU are just one part of a comprehensive quality assurance process.

All the Foundation Course teams at The OU had educational technologists contributing to their deliberations. These colleagues played a crucial role in the design of teaching texts and assessment material for use by students studying largely independently at home. Without them we might not have defined course and unit objectives, had ITQs and SAQs, adopted less formal writing styles, or had CMAs.

We also had the support of BBC staff. Obviously their experience and expertise was invaluable in preparing TV and radio programmes to accompany the course, but as full course team members they also contributed to the improvement of the written materials. They helped develop the following rationale for the effective use of OU science broadcast TV programmes:

- explain difficult concepts using animations and models
- experiments that can't be done at home — or even in a lab
- take students into the field
- give students experiences that are difficult or impossible to provide even in conventional universities

Early on in planning the Science Foundation Course we agreed that students should not only learn about science, but they should also *do* some science, despite not having access to conventional teaching laboratories. 'Doing science' was delivered by a large home experiment kit (HEK) about the size of two under-worktop fridges, and at the Foundation Course summer school. Having decided to leave practical geology to the first second-level earth science course, we were not much involved in designing the first HEK.

The role of part-time staff in supporting students should also not be underestimated. Part-time tutors (now called Associate Lecturers) gave academic support to students through not only marking TMAs, but also by providing constructive comments on students' work, by answering queries over the phone and by giving regionally based tutorials. Tutor-Counselors provided non-academic support and advice to students.

Conclusion: keys to the success OU Earth Sciences

Looking back over a wonderfully enjoyable career at The OU I believe that the success of OU Earth Sciences has been built on the following:

- strong early vision and leadership
- excellence in scholarship, in research and teaching, and above all in the systems and methods which help people to learn and to succeed
- the dedication and enthusiasm of OU students and part time staff, and the OUGS, contributing greatly to our reputation

Endnotes

[1] History of the Open University at http://www.mcs.open.ac.uk/80256EE9006B7FB0/(httpAssets)/F4D49088F191D0BF80256F870042AB9D/$file/History+of+the+Open+University.pdf

[2] Walter Perry 1976 *Open University: a Personal Account by the First Vice-Chancellor*. Milton Keynes: The Open University Press

[3] Obituary for Walter Perry at http://www.guardian.co.uk/news/2003/jul/21/guardianobituaries.highereducation

[4] Obituary for Mike Pentz at http://www.independent.co.uk/news/people/obituaryprofessor-mike-pentz-1621848.html

Is fieldwork relevant to earth sciences in the twenty-first century?

Prof. Nigel Harris

OUGS President 1995–1996 and present President

Abstract only

In recent years it has become possible to collect a rapidly increasing volume of scientific information using a plethora of novel techniques; these data-sets are transmitted and analysed by a formidable array of innovative software. This is true across the range of the earth sciences, but particularly in fields of remote sensing and geophysics. These developments have opened up new avenues of research, but they have also allowed strategy groups from some UK universities to question the value of providing students with fieldwork experience within the curriculum. In contrast, many US universities have been placing increasing emphasis on field education; a recent article in a leading international newspaper of the earth and space sciences states, "the resurgent interest in field education represents a renewed appreciation for basic skills needed by almost all geoscience professionals, and balances other equally important theoretical and laboratory-oriented educational experience necessary for geoscience students" (Whitmeyer 2009). Similar statements from UK geoscience employers have emphasised the invaluable benefits of field training in observation, 3D data collection and model testing.

In this presentation I offered contrasting examples of current research in Tibet and in the Himalaya, where fieldwork has been critical in facilitating scientific breakthroughs in our understanding of Earth processes and their relationships to climate change. I demonstrate that remote and field techniques are entirely complementary approaches and that the awesome power of computer analysis serves to amplify the significance of field studies. Field campaigns have now become essential for grounding our theoretical models and interpretations of the observed world, thus preventing us from constructing an alternative screen-bound 'reality'. The development of field skills for understanding earth and environmental sciences has never been more important than it is today.

Reference

Whitmeyer, S. J., and Mogk, D. W. 2009 'Geoscience field education: a recent resurgence'. EOS, Trans Amer Geophys Union 90, 385–6

Book review

Walton, David W H (ed) 2013 *Antarctica: Global Science from a Frozen Continent*. Cambridge University Press (ISBN 978-1-10700-292-7; hardback, xii + 342pp; £35)

Important though textbooks are, they date quickly and often gather dust beyond graduation. This is not a textbook. It is a nicely presented hardback with quality colour illustrations; and presents a cutting-edge overview of Antarctic Science, ranging from geology and space science, to meteorology, marine biology and oceanography. The contributors are specialists in their fields.

The book will be of most interest to students of environmental or earth systems science, climate change or oceanography, and is pitched about [OU] level 2.

'Discovering explorers' outlines exploration of the continent. A poem by Scott's geologist, Debenham, is included, but not Ponting's picture of Debenham preparing specimens. Wilson found fossil plants in the coal shales, and Scott noted the aurora in his journal.

'A keystone in a changing world' by Bryan Storey reviews the tectonic and geological history of Antarctica, once part of the Rodinia and then the Gondwana supercontinents. The southward migration of Gondwana, and its subsequent breakup are charted, and related to changing climatic conditions. Volcanism associated with an inferred mantle plume began at 183Ma, and the extensive dykes and sills of the Transantarctic Mountain Range may be the conduits. These mountain chains are now largely ice-covered. By 130Ma the South Atlantic had opened, and at 35Ma isolation was completed with the opening of the Drake Passage, and onset of the Antarctic Circumpolar Current. Rotation of microplates may explain misalignment of the Transantarctic and Ellsworth Mountains, and microplate subduction is implicated in the formation of the South Sandwich Island arc.

'Ice with everything' deals with the formation and global significance of ice, and ice core analysis. Some explanations are in boxes (e.g. Milankovitch cycles), others in the main text (e.g. ozone hole). 'Space science' includes the ionosphere and aurora, cosmic ray detection, and the IceCube neutrino telescope, as well as more conventional astronomy. Read the chapter on 'Living and working in the cold' and the 'Visiting Antarctica' appendix before you pack.

Some topics deserve fuller coverage. Joseph Hooker's *Flora Antarctica* [London: Reeve, 1844–59] was a landmark study, but neither the distinctive flora, nor the phytoplankton receive more than a mention; whereas the chapters on collaborative science and the Antarctic Treaty seem too long. Those in search of more depth will benefit from the extensive bibliography. I noticed a missing index entry, and one typo.

Anyone with a serious interest in Antarctica will find this book worthwhile.

— Peter Blackett, BSc (Hons) Open

Book review

McGuire, B. and Maslin, M. (eds) 2013 *Climate Forcing of Geological Hazards*. London: John Wiley and Sons Ltd (Wiley-Blackwell) (ISBN 978-0-47065-865-9; hardback, 311pp; £75)

As this is a subject in which I am very interested, I was keen to read this book, but found that I had already read most of it previously. The book originated as a theme issue of the journal *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* (volume 369, issue 1919) published in 2010. It is claimed that the original papers have been 'materially changed and updated', although a quick random check indicated that this claim does not apply to all of them.

The first chapter gives an overview of the types of geological hazards, such as volcanic activity, seismic activity, flooding and landslides — both terrestrial and submarine — that may be expected as a result of climate change; the mechanisms that may trigger them and the environments in which they may occur, together with some of the evidence of past occurrence of such hazards. The next chapters look at climate change projections from the IPCC- AR4 and how they will affect geological and geomorphological activity, and investigate climate modelling and emission scenarios on a global and regional basis with the possible impact on mitigation and adaptation to geological hazards, where different environmental settings will have different responses to climate change.

Three chapters cover the possible effects of melting ice and increasing sea level on volcanic activity, on magma generation, and on faults and earthquake hazards, providing evidence from the last post-glacial period and the ways of predicting future events. The links between earthquake activity in the Eastern Pacific and El Niño events is another topic covered, as is the possibility of tsunamis resulting from submarine landslides and the climatic events that can influence such slope failure.

Landslides in different mountainous regions are the subjects of a further three chapters, looking at how increasing temperatures and higher precipitation affect the stability of mountain slopes, causing increasing hazards by rock and ice falls and debris flows. The final two chapters investigate the sensitivity of gas hydrate deposits in ocean sediments and permafrost to a changing climate, and their role in past and future global warming.

Each chapter, being based on an academic paper, is provided with an abstract and is well illustrated and extensively referenced. I would like a book at this price to have undergone more rigorous proof reading, as several typographical errors jumped out at me, but that aside it is an interesting and topical read, providing insight into how natural geological hazards can be affected by the changing climate.

— Suzanne Grain, BSc (Hons) Open, BA (Hons) Wales

More than meets the eye: combining the real and the virtual in evolutionary science

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Abstract

The question of 'virtual' versus 'hands-on' experience in OU science teaching is very topical, but that's not what this paper is about (sorry!). Rather, it's about the constructive integration between the two kinds of evidence in research today, particularly in my own area of specialist interest — evolution.

Science involves testing between competing explanations for some initial observation(s) by reference to further evidence, to see if one hypothesis predicts (or retrodicts) what the latter shows better than other hypotheses, including the effects of chance alone. Hypotheses that repeatedly survive testing against different lines of evidence, without being falsified, and that satisfactorily explain yet more otherwise unintelligible phenomena, become our working scientific theories. But in relation to the understanding of life, the distinction between sound science, such as the theory of evolution by means of natural selection, and unscientific fantasies, such as creationism, is not always clear-cut, with some ideas lurking on the borderline, such as the fashionable by flaky 'Gaia' hypothesis (founded on a theoretical abstraction, but lacking adequate supporting observational data). At issue, then, is what constitutes suitable evidence, to which the relationship between direct observation and virtual representations is relevant.

As evolutionary science has matured, it has made increasing use of systematic means for abstracting virtual patterns from large databases instead of on subjective judgement from primary observations, as illustrated, for example, by the replacement of old-style typological taxonomy by statistical recognition of 'natural groupings'. Such abstractions in turn become the virtual evidence to be considered in relation to theory, serving as proxies for the primary observational data. Because of their ability to process large amounts of data very rapidly, computers have naturally played a major role in the development of such virtual representations. Examples include the use of serial grinding tomography for the visualisation of otherwise hidden morphological features, computed finite strain analysis to analyse functional morphology, tree-building algorithms for phylogenetic reconstruction, and biogeochemical box models to assess the role of life in the Earth system.

Uncritical dependence on such virtual representations, however, can mislead interpretation. A prominent trap in considering the fossil record is that of organising primary data according to erroneous assumptions about past conditions based on what we see around us today. The deleterious effects of this 'tyranny of actualism' — an over-zealous form of uniformitarianism — are demonstrated by some regrettably popular myths in the literature concerning the history of so-called fossil 'reefs'.

Another consideration is the question of how the large amounts of necessary primary data can be collected in the first place. In some cases, high-tech automated methods of data-acquisition have come to the rescue of providing abundant proxy data for historical processes and relationships, ranging from the use of isotope geochemistry to analyse rates of shell growth and carbonate production in extinct shelly organisms to DNA-sequencing for the assessment of evolutionary relationships. In other cases, though, there is still not better alternative to myriads of simple observations being made and uploaded to data-gathering websites by lots of motivated people — i.e. 'citizen science': productive UK examples include The Woodland Trust's 'Natures's Calendar', The RSPB's 'Big Garden Bird Survey', and from nearer to home, of course, the 'Evolution Megalab' and 'iSpot'. Such enterprises can yield science that is just as sound as that produced by giant hadron collider or mulit-billion dollar satellites.

Thus the future of science is certainly not limited to the activities of white-coated boffins in expensive labs — and this is one good reason why science education should remain as open as possible to all who wish to engage with it … justifying The OU's contribution to that end.

The question of 'virtual' versus 'hands-on' experience is certainly topical in relation to OU science teaching. I suspect most readers of this article will share my view that both are needed for effective learning and scientific discovery alike. Here, to make my point, I illustrate the integration between them in research today, focusing on my own field of interest, evolution (especially that of the rudist bivalves — my research speciality), after some remarks on what constitutes science in principle.

What is, and isn't science: the fundamental role of evidence

Science is about using directly sensible evidence to try to get to the truth of things. To put it more formally, it involves testing between competing explanatory hypotheses for the physical nature of phenomena or their history and behaviour by reference to empirical data: if the available evidence is found to match the expectations of one hypothesis better than those of the alternative(s), then that hypothesis is preferred. Think Sherlock Holmes, as opposed to 'He done it!' style tabloid headlines based only on a handy photo of someone looking weird or shifty. Hypotheses that are repeatedly supported by different lines of evidence, without being falsified, and that go on to furnish explanations for yet other previously unintelligible phenomena become working scientific theories. Through this process of what might be thought of as the evidence-based natural selection of ideas, science should generally evolve towards correct explanations.

A timely example is Wegener's (1912) theory of continental drift, which enjoyed its centenary as the OUGS celebrated its 40th anniversary. Wegener's corroborative evidence for the

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jigsaw-like matching of formerly connected continental margins ranged from fossils to fold-belts (see, for example, Wagoner 1996). But, unfortunately, Wegener speculatively saddled his pattern-based theory with an implausible mechanism, which put off general acceptance of continental drift itself until plate tectonic theory rescued it in the 1960s by providing a credible mechanism, itself corroborated over the next few years by diverse lines of evidence (as students of even the earliest, revolutionary OU geology courses were to learn within a decade).

Turning to evolution, numerous test cases besides the best known examples involving peppered moths, guppies and banded snails (Fig. 1; see also Silvertown *et al.* 2011) have repeatedly confirmed the validity of the Darwin/Wallace theory of natural selection, drawing on evidence both from field observations and from manipulation experiments (as those fortunate enough to have studied the subject with The OU will know). It is still the only rational explanation that we have for that most remarkable aspect of living organisms: the integral adaptation of their form and functioning to their habitual conditions of life. Moreover, with the support of genetics it has proved capable of explaining even such otherwise puzzling phenomena as apparent altruism between organisms such as social insects (Dugatkin 2006). In short, to borrow a legal expression in the news as I write this*, it is 'beyond reasonable doubt' (* the reference being to a judge's publicised frustration at the apparent inability of a jury to understand the meaning of the expression).

It follows, then, that hypotheses that cannot in principle be tested by recourse to empirical evidence, such as divine creation myths (including 'Intelligent Design') are doomed to languish as non-starters in the scientific quest for understanding of the real world (Skelton and Slapper 2008) — too bad for 46% of people recently polled in the USA on their beliefs concerning human origins (Barooah 2012), as well as for other exponents of such religious credulity elsewhere.

Figure 1 A handful of live specimens of the brown-lipped banded snail, Cepaea nemoralis*, collected (and put back afterwards!) from a single site near The Open University at Walton Hall. The remarkable genetic polymorphism of colour and banding shown by this species was the subject of a highly successful 'citizen science' project set up for the Darwin bicentenary year in 2009 (Worthington* et al. *2011) (photograph by P. Skelton).*

Because of the daunting complexities of life, however, the distinction between sound science and groundless fantasies, as illustrated by the examples above, is not always clear-cut. One such borderline case is the speculative 'Gaia' hypothesis of Lovelock (1989; and other, more popular accounts), which has acquired a following not only among New Age wackos — to the obvious embarrassment of its founder — but even among some (less forgivably) impressionable geologists. Based on idealised model systems such as 'Daisy-world', in which ambient conditions are regulated by various feedbacks, it asserts that life interacts with the Earth system in such a way as to maintain conditions tolerable for its survival, thereby creating a sort of self-regulating 'superorganism' conserved by global homeostasis.

Despite the impressive self-regulation shown by the models, the Gaia hypothesis nevertheless faces severe problems of theoretical plausibility, definition and real-world evidence (Skelton *et al.* 1997). An immediate concern is the purported analogy with organismal homeostasis (Williams 1992). Homeostasis in organisms involves the intricate co-adaptation of parts, involving discrete sensors and response mechanisms — for example, involuntary shivering in response to the sensory stimulus of feeling cold, or sweating when hot, which are just two of the many components involved in our own thermoregulation. As noted above, the only rational explanation we have for such functionally integrated adaptive devices in organisms is evolution by means of natural selection, owing to non-random differential reproductive success between individuals exhibiting heritable variations. Clearly, no such explanation can be applied to the Earth as a whole (unless we've missed the evidence for all those unfit baby Earthlets that fell by the wayside!). Rather, it seems that Lovelock may have confused mere dynamic equilibration, for which life is not a necessary component, with the biologically evolved phenomenon of physiological homeostasis in organisms.

A thought-experiment will illustrate the distinction. Imagine a pan of boiling water sitting on a stove with a cooling coil rising from its lid, in which the steam condenses to water that drips back down into the pan below. As long as heat is supplied by the stove (and the water doesn't boil away), the water in the pan will maintain a constant temperature – its boiling point. However, that equilibrium state would change to a new (if only slightly different) one if, for example, our imaginary experimenter were to put some salt in the water, thereby raising its boiling temperature. A truly homeostatic pan, by contrast, would have some sensitive device for detecting the added salt coupled with another mechanism for excreting it, thereby regaining the original temperature. Even complex dynamic systems with myriads of feedbacks, whether or not mediated by living organisms, may settle into transient equilibrium states, chaotically shifting between them when sufficiently perturbed. So the challenge faced by the Gaia hypothesis is to demonstrate that the Earth-life system transcends being just a vastly more complex version of our imaginary pan by virtue of having somehow acquired genuine homeostatic-like capabilities — though not by any currently known evolutionary process. This theoretical stricture alone does not falsify the hypothesis,

of course, but it does set a high bar in terms of the evidence required for it to qualify as a legitimate scientific theory. So, let's now consider the evidence.

The first point to be clear about, lest there be any confusion, is that Daisy-world and the like do not constitute virtual evidence in support of the Gaia hypothesis. Rather, they are purely speculative formal demonstrations of how a Gaian world might operate — still to be tested against real world data (though to be fair to Lovelock, I do not believe that he has suggested otherwise). In other words, is the real world really like Daisy-world? The problem for testing the proposition — despite the numerical rigour of the models — is the vagueness of the reference to 'life' in the Gaia hypothesis: for how much of the global biota does "the climate and chemical composition of the Earth's surface environment" (Lovelock 1989, 215) have to remain 'tolerable' for the system to qualify as being Gaian? Are we 'all in this together', as the saying goes? Clearly not, literally, as far as species go, as the fossil record reveals that the vast majority (probably at least 99%) of those that have ever existed have become extinct. So what evidence might conceivably confirm the Earth to have developed along Gaian lines, rather than merely being a chaotic dynamic system that happens (fortunately) to have been adaptively tracked by evolving life forms since their first appearance? Think of the latter as a giant 'null hypothesis'. Against that, can we see any suggestive trend in, say, the history of ecosystems? I am not aware of anyone having attempted this in any rigorously objective fashion, but it is not hard to think in broad terms both of some obvious 'gains', arising from the invasion of the land, for example, and 'losses', such as those lush polar forests of the Cretaceous greenhouse Earth (Spicer 2003) that are now replaced by icy wastes (Gaia's 'tough love', or just 'tough luck'?). The long-term climatic change involved in the latter demise hardly proclaims supportive planetary homeostasis, but nor can it be excused from the Gaian script on the grounds of resulting from some unfortunate extra-terrestrial perturbation, as with some of the great mass extinctions. So the pattern of past outcomes is not encouraging.

Alternatively, if just the continuity of some life, somewhere, is the point — which the universality of DNA certainly confirms for life on Earth — then how can we decide whether that has been thanks to the tending hand of Gaian self-regulation or to mere evolutionary muddling through? A consideration of life's general role in feedbacks seems to be called for: can a clear beneficial bias be detected? For the proponents of Gaia just to pick out examples of stabilizing negative feedbacks involving organisms, such as the production of DMS by phytoplankton (Charlson *et al.* 1987), is not good enough because all manner of feedback loops, both negative and positive, can be expected in a chaotic system whether or not life is involved — indeed, that's what explains the chaotic behaviour. Cherry-picking of evidence is mere advocacy, not sound science. In fact, counter-examples of positive feedbacks to climate change involving living organisms can also be cited, such as the contribution to climatic warming during Quaternary interglacial periods resulting from the net effusion of CO_2 caused by the rapid aggradational growth of coral reefs keeping up with rising sea levels (Gattuso *et al.* 1993). Nothing short of an overwhelming predominance of Gaian feedbacks mediated by organisms needs to be demonstrated if the hypothesis is to transcend being just a nice idea. In the absence of such evidence (already cast in doubt by a recently announced critique by Tyrrell 2013), it may yet end up in science's waste-bin of failed hypotheses, along with phlogiston and cold fusion.

Clutching at straws of cherry-picked or even dodgy data is indeed the standard resort of people who have backed the wrong horse in scientific debates, such as those who persist in denying the anthropogenic forcing of climate change despite ever stronger evidence for it (see Curtis 2012). As in the previous case, the Polar Regions provide the most telling witness because they show the most extreme response to changes in global mean temperature: their large-amplitude climatic fluctuations reflect changes in poleward heat transport from the main reception area for solar radiation between the Tropics, where mean temperatures, by contrast, vary much less. The progressive southward collapse of ice shelves on the Antarctic Peninsula (Fox 2012) and the remorseless retreat and thinning of Arctic Sea ice over the last few years (Greene 2012), for example, starkly testify to the climatic impact of the rapid recent historical increase in atmospheric CO_2 to levels not experienced by the Earth for at least the last 800,000 years and perhaps not even since some 14 million years ago (Tripati *et al.* 2009; see also Vidal 2013, concerning the latest record levels). The most obvious novel inputs behind this alarming trend are the burning of fossil fuels and the widespread destruction of major surface sinks for carbon such as rainforests and wetlands (Siegenthaler and Sarmiento 1993; see also Curtis 2012). Given the likely dire consequences of current global warming, combined with ocean acidification (Hoegh-Gulberg *et al.* 2007) and sea-level rise, both for our successors and for global biodiversity in general, this is far too serious a topic to be so cynically misrepresented as it is by environmentally unconcerned quarters of the press wilfully seeking to pander to the ill-informed prejudices of their readers. (I should add that this is no hollow accusation, as I, like others no doubt, have been approached by a journalist from one such broadsheet, keen to discuss 'The Cretaceous World' with me for its demonstration that large-scale climate change had occurred naturally in the past, hence — so he supposed — was nothing to worry about now. But when I then provided him with data to show that both the exceptional rate of climate change today and the profound difference in global context rendered his comparison false, his interest abruptly waned and I heard no more from him…).

Reliable evidence is thus the gatekeeper to scientific truth, but what forms may it take? This question brings us back to the relationship between direct observation and virtual representation, which I now explore by reference mostly to examples from research on rudist bivalves.

'Real' and 'virtual' evidence in evolutionary science

Some hypotheses can be adequately tested by simple observation of real objects. For example, all that is needed to confirm the hypothesis that dinosaurs once lived in Antarctica is to find their fossils there (the answer is yes, they did, by the way). Testing of more complex hypotheses may call for systematic compilations of data, however, such as the interpretation of ancient depositional environments from graphic logs (as those who have had the benefit of studying field geology with The OU will recognise).

As the theoretical and technical methods for studying life and its evolutionary history have matured, increasing use has been made of various systematic means for abstracting virtual patterns from large observational databases. Such methods are

objective in the sense of being repeatable by anyone applying the same method to the same data-set, in contrast to subjective judgements extrapolated from primary observations (sometimes caricatured as 'Just-so stories'). An example is the replacement of old-style typological taxonomy by the statistical recognition of natural groupings of variable individuals — in line with what Ernst Mayr (e.g. 2002, 81) referred to as 'population thinking' (although there is, regrettably, still a large historical backlog still to catch up on). Figure 2 shows a simple illustration, based on a rudist bivalve genus, *Pachytraga*. When Paquier (1905) erected this genus, he based it on a previously named species, which thus became *Pachytraga paradoxa* (Pictet and Campiche) (Fig. 2a). At the same time, he judged some rather more slender specimens of the same age in his collection to belong to a separate species, which he called *P. lapparenti* (Fig. 2b). However, a series of bivariate plots of measurements later taken from a large number of specimens of *Pachytraga* of this (Early Aptian) age shows only a single indivisible scatter of data points around a slightly allometric growth curve for each plot (Fig. 2c; Skelton and Masse 1998). No statistical justification could be found for upholding Paquier's subjectively separated 'species' and they were therefore merged ('synonymised') under the older species name, *P. paradoxa*, which, by taxonomic convention, has nomenclatural priority. Combining that conclusion with measurements of stratigraphically older specimens (those referred to *P. tubiconcha* in Fig. 2), which clustered along the same allometric lines on the plots, allowed the further inference of a single evolving chronospecies lineage displaying phyletic size increase (an intriguingly frequent phenomenon among rudist lineages). Hence, in this case, it was the virtual evidence — the pattern shown by the bivariate scatter plots — abstracted from primary observations (the measurements) that directly underpinned the evolutionary interpretation. Bivariate plots like these readily make the point because they are relatively easy to

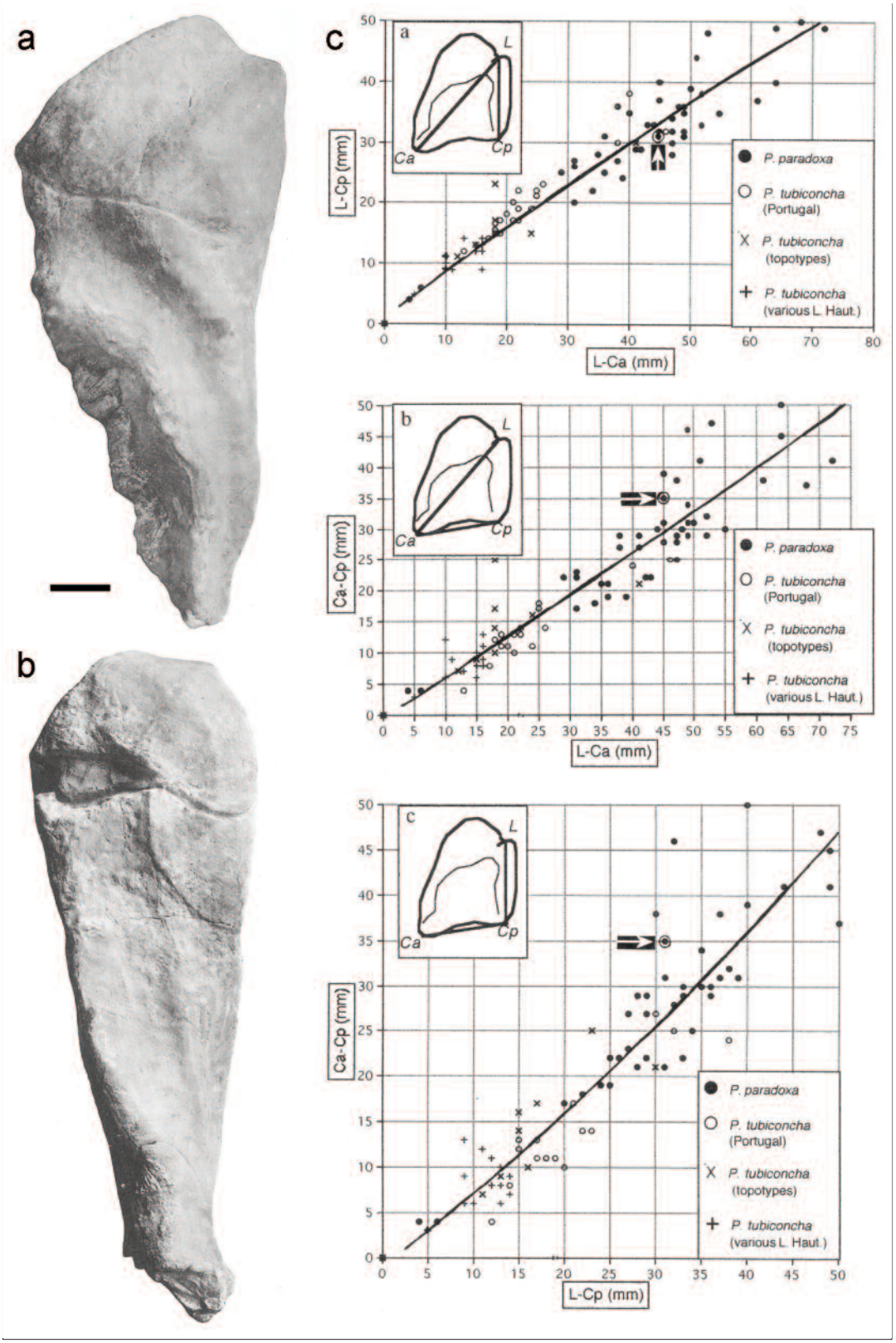


Figure 2 The rudist bivalve Pachytraga paradoxa*: (a, b) two specimens originally figured by Paquier (1905) and attributed by him to two different species,* P. paradoxa *(a) and* P. lapparenti *(b), subsequently synonymised by Skelton and Masse (1998); scale bar for both is 10mm; (c) bivariate scatter plots for the three commissural dimensions defined by the ligamentary invagination site (*L*), the anterior carina (*Ca*) and the posterior carina (*Cp*), as indicated by bold lines on the inset diagrams. Lower Aptian specimens are shown as black circles (arrow indicates the selected type specimen for* P. paradoxa*). Other points are all from the smaller Hauterivian species,* P. tubiconcha.

interpret visually, but more sophisticated representations of multivariate data are also possible and are widely used in modern taxonomic work.

Because of their ability to process large amounts of data very rapidly, computers have naturally played a major role in the development of such virtual representations. Diverse examples range from the synthetic imaging of morphological features hidden from the naked eye, via models of dynamic properties, to portrayals of inferred historical relationships such as phylogenetic trees. One approach for the first of these examples involves making multiple cross-sectional images and using a computer program to stack them together ('computer assisted tomography', or CAT) so as to yield a virtual 3D image, which can then be spun around and viewed from different angles on a monitor screen, and even virtually re-sectioned in new orientations and/or colour-coded for different components. The cross-sectional images themselves may be obtained either non-destructively using X-rays, for example, or by progressive grinding away of the specimen with repeated digital photographing at microscopically close intervals. The latter method, although destructive, offers certain advantages for fossil material such as the retention of natural colour, if desired, and the distinction of fine differences in crystalline texture (e.g. shell versus calcitic matrix) that may not be resolvable using non-destructive methods. Figure 3 illustrates the virtual imaging of the internal shell features of another rudist bivalve, *Polyconites verneuili*, using serial grinding tomography on a specimen that was entirely encased in limestone (Pascual-Cebrian *et al.* 2012). Of course, the original specimen no longer exists because it was entirely ground away, but the virtual image of it obtained thereby reveals internal features such as the hinge teeth and projecting shelly muscle supports that would have been difficult if not impossible to display through laborious excavation of the hard matrix filling the fossil shell. And, as an extra bonus, the virtual image can readily be e-mailed to multiple recipients as an attachment, unlike a prepared specimen.

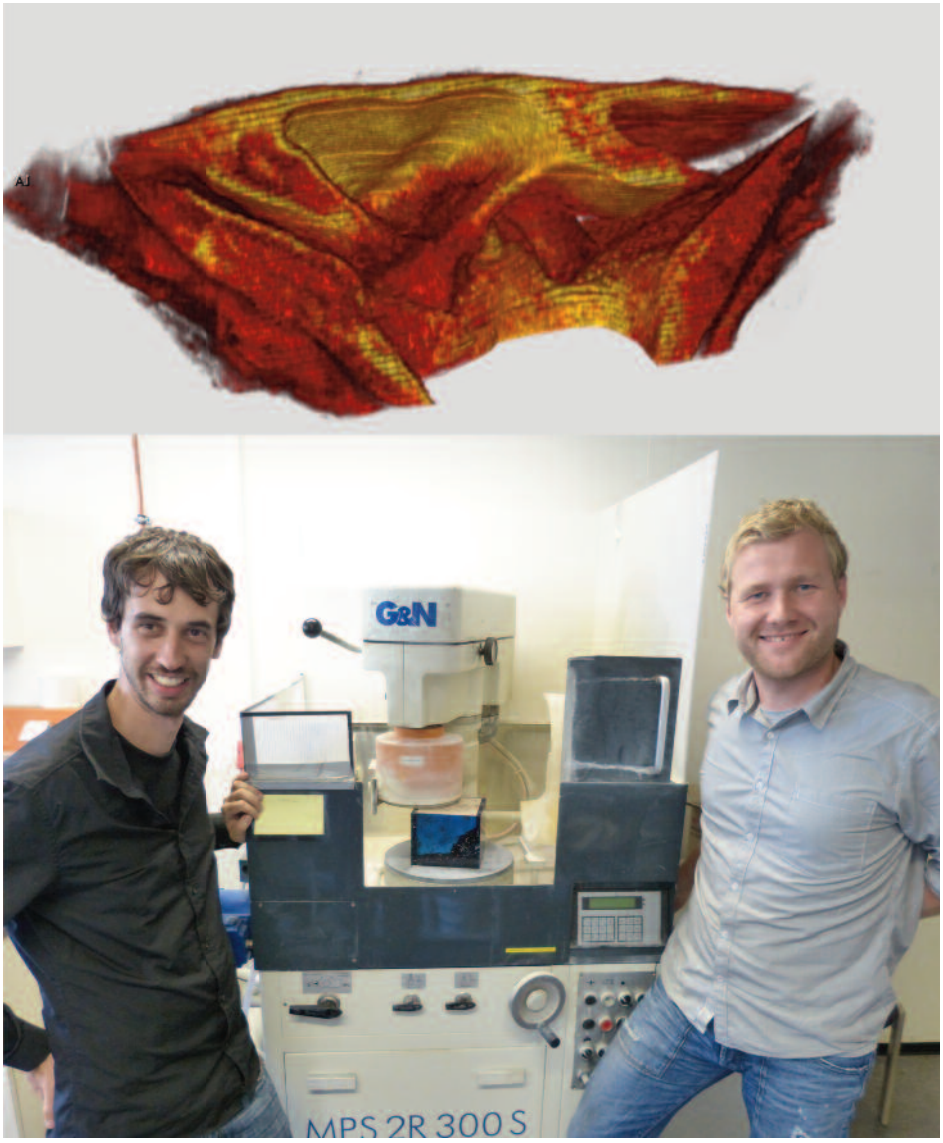


Figure 3 (top) CAT reconstruction of internal features of the shell of the Upper Aptian rudist Polyconites verneuili*, from serially ground sections, based on the work of Pascual-Cebrian* et al. *(2012; image courtesy of the authors). The virtual section shows the upper (left) valve above, with its hinge teeth and shelly muscle supports projecting down into the partial right valve below. (bottom) Two of the authors of the study, Enric Pascual-Cebrian (left) and Dominik Hennhöfer (right) with the serial section-grinding machine, in the laboratory set up in Heidelberg University by the late Stefan Götz (photograph by P. Skelton).*

In addition to morphology, dynamic properties such as biomechanical characteristics can also be virtually modelled, as opposed to being directly measured in laboratory tests. One approach is to divide a virtual image of an object, such as a digital photograph, into a mosaic of many tiny elements and, making reasonable assumptions about the physical properties of the materials involved (e.g. bone and ligament), to compute how given stresses would be transmitted between the elements so as to reveal the resulting distribution of strain. Besides the obvious medical applications of such 'finite element analysis' (FEA), it has also been used to investigate the functional morphology of extinct organisms such as dinosaurs, a notable example being Emily Rayfield's (2004) elegant analysis of the skull of *Tyrannosaurus rex*. Her study confirmed that the relatively loose articulation of the facial bones, which would seem to have weakened the overall cranial structure, nevertheless played an effective shock-absorbing role that reduced potentially hazardous localised tension, allowing both powerful biting and tearing, in agreement with the somewhat gory-sounding 'puncture-pull' hypothesis for the animal's feeding mode (so I would certainly urge caution on that innocent child depicted with his or her dinosaur play-mates in Cincinnati's infamous creationist museum).

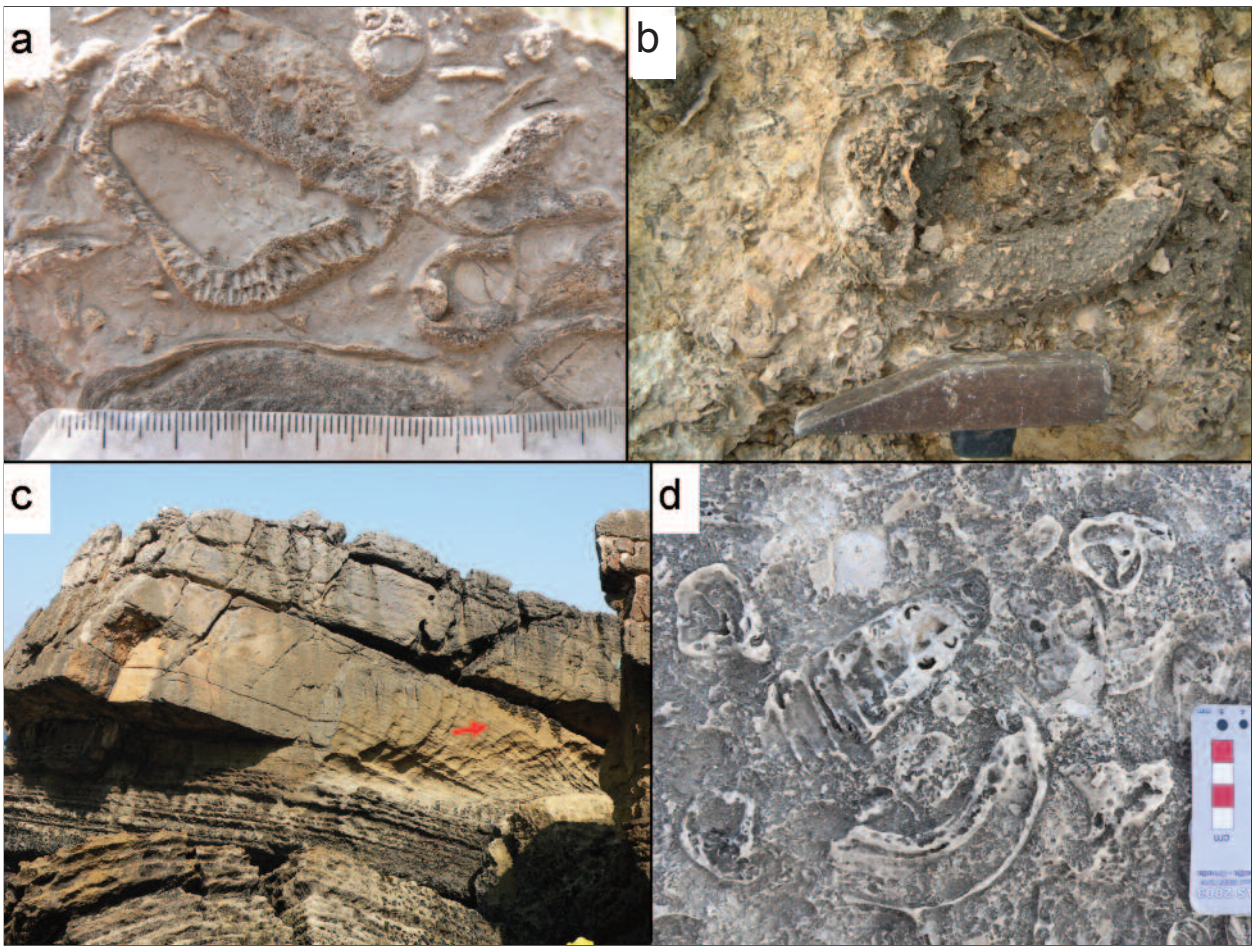
Turning to evolutionary history, attempts to reconstruct phylogenies before the advent of computers — especially personal computers — commonly suffered from a partial, hence biased consideration of evidence. This is not surprising, though, in view of the myriads of characters that might potentially be used in any given case and the vast numbers of theoretically possible rooted

trees for even a relatively small number of compared taxa (e.g. over two million for just nine taxa): in these circumstances researchers naturally tended to emphasise the apparent phylogenetic implications of whichever characters and/or distributional data they considered most reliably informative. The problem with that approach was that different experts not infrequently differed in their personal assessments of the latter, such that phylogenetic debate often ended up being a sterile contest of kudos between opinionated specialists. Again, computers have come to the rescue by virtue of their capacity for absorbing huge amounts of taxonomic data and trying them out at electronic speed on virtual forests of possible trees (even while the specialists are arguing over their coffee), so as to come up with preferred solution(s). Another crucial component of this revolution in phylogenetic reconstruction was the parallel development of systematic methods for cladistic analysis of the input data. These methods are aimed at finding (again, objectively) either the most parsimonious tree(s) with respect to inferred changes in morphological characters, or, alternatively, the most 'likely' tree(s) with regard to nucleotide sequence data, for which the relative probabilities of given types of base substitution can be assumed from prior studies. Needless to say, the accelerating pace of technological advance in DNA sequencing in the last few decades has led to a swelling torrent of available molecular character data. As a result, since the latter part of the last century, the business of phylogenetic reconstruction has grown from being the arcane practice of closeted specialists, either just accepted uncritically or, conversely, taken with a pinch of salt by others, to becoming an indispensible conceptual tool in a wide range of biological investigations.

Such phylogenetic 'tree-thinking' in evolutionary palaeontology can again be illustrated by reference to rudists. All but a few of the most primitive genera in a prominent clade of Early Cretaceous rudists with elongate tubular shells known as caprinoids have blind-ending 'pallial canals' longitudinally penetrating the shell wall of one or both valves (Fig. 4a). Many caprinoids attained large size, with openly spiral to croissant-shaped shells lying prostrate on current-swept substrates, such as the tops of mobile bioclastic banks (Fig. 4b, c, d), on the carbonate platforms that developed episodically along the Tethyan-Atlantic oceanic sluice and beyond into the Pacific Basin. The pallial canals probably conferred some biomechanical benefits, such as reducing the risk of brittle fracture, as well as allowing rapid growth to large size, and hence stability, of the recumbent shells.

Cladistic analysis (Skelton and Smith 2000; Fig. 5, *opposite*) confirmed previous suggestions that the caprinoids consisted of two sister-groups, one of largely Old World distribution (though with a few primitive Caribbean representatives as well) and the

Figure 4 (a) Natural section across a caprinoid rudist (the caprinid Offneria murgensis*) in a Lower Aptian carbonate platform succession in northern Sicily (Cefalù), showing the characteristic pallial canals in the valve walls (scale in cm/mm); (b) bedding plane view of a recumbent specimen of the primitive caprinid,* Pachytraga paradoxa *(which lacks canals;* see also *Fig. 2), preserved in life position in the Lower Aptian of Portugal (São Juliãu); (c) massive, 3m thick unit (centre) in the Lower Aptian of Portugal (Crismina, Cascais), showing clinoforms (red arrow) from a migrating bank; (d) shell debris of rudists and large gastropods swept off the bank top onto the clinoforms shown in (c) (all photographs by P. Skelton).*



other almost entirely confined to the Caribbean Province plus Pacific seamounts. The first sister-group is now referred to the Family Caprinidae and the second to the Family Caprinuloideidae (Skelton 2013). This phylogenetic conclusion in turn entails two intriguing inferences, the first concerning the trigger for adaptive radiation in the caprinoid clade and the second, an insight on Early Cretaceous palaeoceanographic circulation. In the first case, the cladistic analysis shows that pallial canals (together with the adoption of enlarged recumbent morphology) evolved independently in the two sister groups. Moreover, the evolution of these features occurred at the same time — around the beginning of the Aptian Age, about 126Ma ago) — in both cases leading to a rapid diversification of species through part or all of the Early Aptian, after which they make a 'Lazarus'-style disappearance from the known record until the end of the Aptian in the New World, and even later, in the Late Albian, in the Old World (Skelton and Gili 2012). Such a coincidence supports the hypothesis that this episode of radiation was extrinsically triggered by propitious changes in global oceanographic conditions, rather than intrinsically by the fortuitous appearance of preadaptive attributes, which in this instance thus had only an 'enabling' role.

Another inference from this phylogenetic analysis concerns the implication of a newly reported caprinoid genus from Japan, again of probable Early Aptian age, for Pacific current circulation. Its unambiguous caprinuloideid (as opposed to caprinid) affinities, and similarities, moreover, with a more primitive form already known from the Mid-Pacific Mountains, supports the presence then of an east to west-flowing gyral current that enabled larval 'island-hopping' of rudists across the Pacific from the Caribbean region, via the constellation of volcanic seamounts that were then scattered across the ocean basin (Skelton *et al.* 2013).

Both these hypotheses are thus again directly supported by the abstracted virtual evidence, in this case provided by the phylogenetic analysis. However, that is not to say that the primary data — the original direct observations of real objects — did not play a part: of course they did, albeit at one remove in providing the basic factual fodder for the virtual evidence. So, both 'real' and 'virtual' forms of evidence have their parts to play in an inferential hierarchy whereby relatively narrow (e.g. taxonomic) primary conclusions in turn underwrite higher-level inferences of wider relevance. (Yes, this is indeed an unashamed plug for the continuing importance of primary taxonomic work!)

One effect of the methodological upgrading of phylogenetic analysis also worth noting, though, is that the expanded mass of primary observations — the identification of character states and their distributions among taxa — increasingly find themselves relegated to lengthy appendices to papers (if not hived away in supplementary online files: after all, who but a diehard taxonomist really wants to wade through all that itsy-bitsy detail?). More often than not, they feature in the main text only as indigestible tables of 0s and 1s, or other character state codes. Meanwhile, the trees abstracted from them take centre-stage as the virtual evidence paraded in support of whatever higher-level evolutionary theories are being propounded. One just has to hope, then, that both the compiler of the primary data and the computer programs are getting things right — which brings us to a consideration of possible pitfalls in this business of hierarchical theorising.

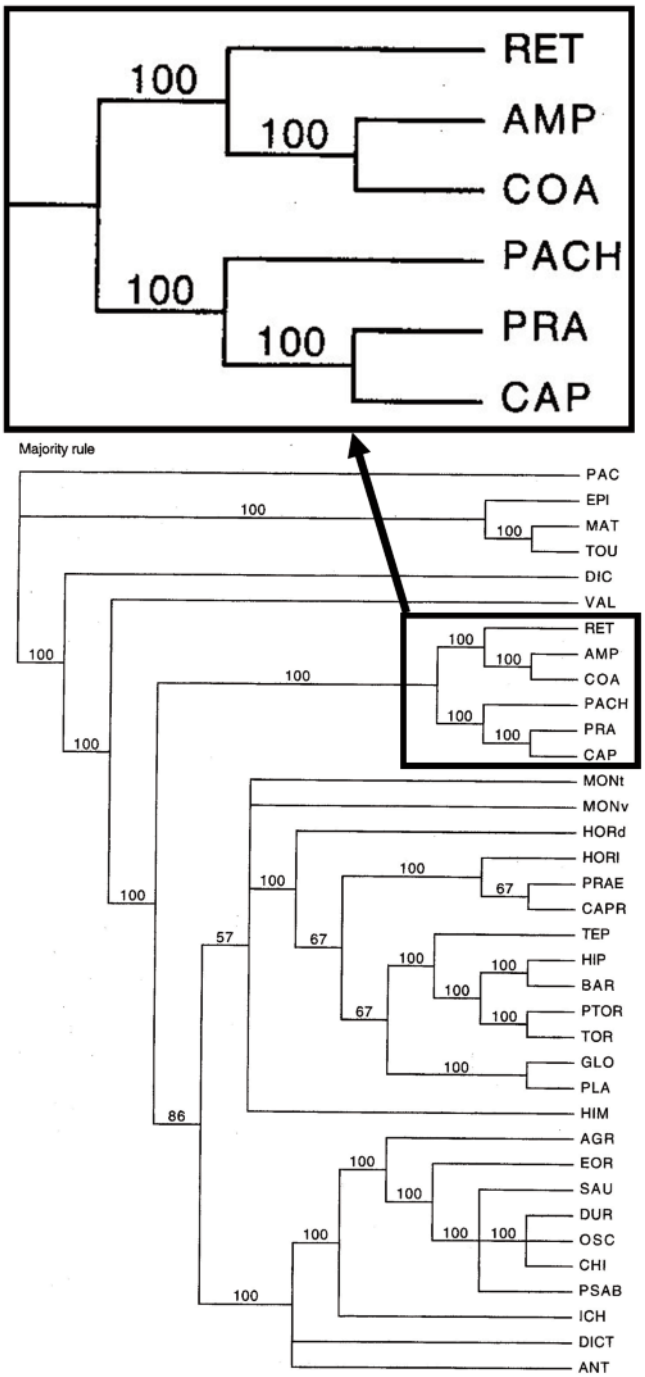


Figure 5 Majority rule cladogram ('100' means all the most parsimonious trees agree for the node below) for selected rudist genera (from Skelton and Smith 2000), with boxed area enlarged to show the distinction between the two caprinoid families, Caprinuloideidae (top three genera, Retha*,* Amphitriscoelus *and* Coalcomana*) and Caprinidae (lower three genera,* Pachytraga*,* Praecaprina *and* Caprina*).*

Traps to watch out for

Essential though virtual representations of data are in modern science, uncritical dependence on them runs the risk of misleading interpretation. Systematic spoilers may be simply technical, such as incorrect stacking or scaling of serial sections in the case of 3D morphological imaging, which yields reversed or deformed reconstructions (all too easy on a computer!), or — more insidiously — they may be conceptual. A common trap of the latter type in considering the fossil record is that of assembling primary data according to erroneous assumptions about

past circumstances based on what we see around us today. The oft-repeated mantra of uniformitarianism that the 'The Present is the Key to the Past', can be over-interpreted (as it was, most famously, by Charles Lyell himself). There is no reason to doubt the constancy of the fundamental laws of physics and chemistry, or, for that matter, the basic Darwinian processes of biological evolution, at least for our geologically monitored nook of space and time. But that assumption does not warrant belief in the conservatism of types of environments (sometimes referred to as 'actualism'). Variations in the amplitude and frequency of sea-level oscillations and changes in oceanic and atmospheric circulation and chemical composition, not to mention accompanying biotic changes, have all contributed to alterations in the characteristics of facies and how they are distributed. Our current perspective on the past from an interglacial episode within an ice-house regime in fact represents a rather exceptional state of affairs in the broader sweep of Earth history. So our 'now' is often not the best place to start from for establishing environmental models to organise geological data from 'then'. A cautionary tale of what might be called the 'tyranny of actualism' includes some regrettably prevalent text-book myths concerning so-called 'rudist reefs'.

The first question to be asked in the latter instance is what image have we in mind when we talk about 'reefs'? Library shelves of literature have concerned themselves with this question, so I'll outline the aspects that I think most would agree upon and cut to the chase of the critical point I'm after. In common parlance, a reef is simply a shallow submarine or barely emergent ridge of rock, shingle or sand — hence a potential nautical hazard. In the present context, however, we are concerned only with those that are apparently armoured by masses of sessile organisms with stony (usually calcareous) skeletons and their debris. The conventional definitive model is obviously that of the tropical reefs of today that are constructed by colonial corals and algae, accompanied by a rich diversity of other reef-dwelling species (I shall bypass the distraction of what to call one of the most extensive tracts of coral mounds in today's oceans, that situated at depths of 500–1200m around the North Atlantic (e.g. Kenyon *et al.* 2003), from which the only nautical threat might be to submarines!).

It is evident from the surface appearance of extant tropical reefs that the clustered growth of colonial corals and of binding organisms such as encrusting algae, together trapping bioclastic debris, have built up wave-resistant frameworks along their external margins, so creating their characteristic relief, as Charles Darwin correctly surmised for the formation of oceanic atolls. But deeper inspection of their foundations by seismic profiling and drilling reveals a complex story behind the generation of such relief. In short, what we see now at the surface turns out to reflect pronounced antecedent topography that was sculpted during earlier emergence when sea level fell as a result of continental glaciation; karstic surfaces on older reef-carbonate foundations are particularly frequent. In tandem with rapid post-glacial sea-level rise, reef frameworks then built up on the antecedent prominences, especially the outer rims of tower karsts, while back-reef lagoons filled more slowly behind with bioclastic debris (Purdy and Winterer 2001). These circumstances favoured the localised upward growth of frameworks supported by robust colonial corals, capable both of keeping pace with rapid sea-level rise and of resisting the wave surge to which they were thus exposed. The hosts of associated species have in turn exploited subtly varying niches in their intricate surface morphology. Hence the characteristics of today's tropical reefs are not simply down to the ecological attributes of the organisms involved, divorced from any historical context, but are the complex product of successive episodes of erosion and aggrading growth of frameworks related to large-amplitude glacioeustatic oscillations of sea level.

How, then, do rudist formations compare with this picture? It is not hard to see why geologists in the past, when confronted with the clustered masses of large shells seen in exposures of rudist formations (Fig. 6a) might have loosely employed the term 'reef' to describe them. The real problem with this usage arose in the latter part of the last century when some authors took this superficial resemblance too literally and attempted to match their observations of rudists with an interpretative model essentially based on modern reefs. Aspects of rudist evolution, such as the appearance of vertically growing elongate tubular shells, were thus interpreted as being adaptive for framework development, with little consideration of the relationships between the growth and taphonomy of the rudists and their surrounding sediments. Later detailed studies of the latter aspects, however, showed such vertically oriented rudists (of 'elevator' morphotype) to have been largely sediment-supported during growth, usually projecting from only a few, to rarely more than 200mm from the surface (with a 'constratal' growth fabric) in contrast to the upstanding, metre-scale self-supporting ('superstratal') frameworks of modern

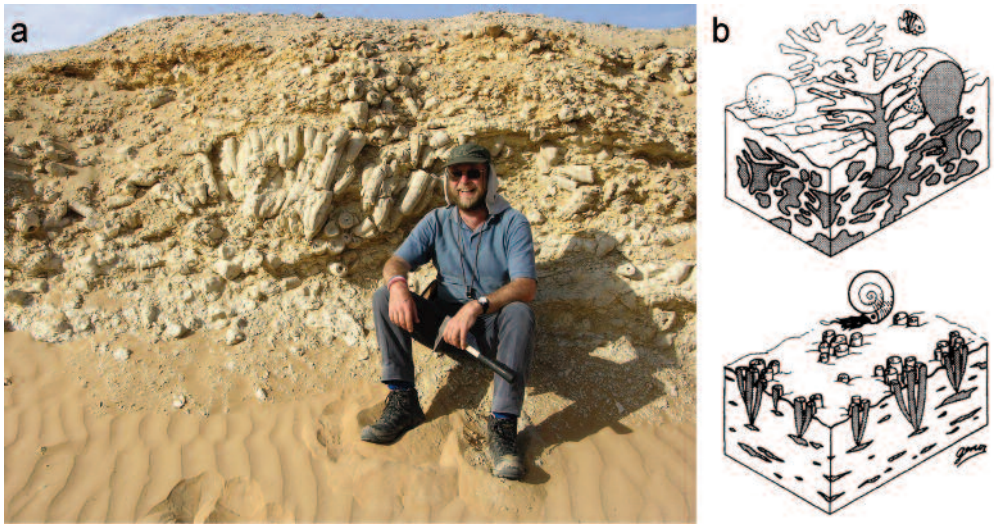


Figure 6 (a) A fine cluster of hippuritid rudists preserved in life position in the Campanian of southern central Oman, with the suitably impressed author as scale (photograph courtesy of Adrian Immenhauser); (b) cartoons to illustrate the difference between a superstratal growth fabric, as in modern coral reefs (above), and a constratal growth fabric, as in most elevator rudist lithosomes (below); artwork by Albert Casanelles-Gili (Gili et al. *1995).*

coral reefs (Fig. 6b; Skelton *et al.* 1995): thus the previously hypothesised adaptation to framework development turned out to be no more than one of those 'Just-so stories' mentioned in the previous section.

Further speculations illegitimately spawned by the older conceptual model included the hypothesis that the seemingly ubiquitous rudists competitively displaced corals from Cretaceous 'reefs'. Such colourful and simply assimilated ideas inevitably found their way into textbooks and popular secondary literature (despite the absence of any supporting evidence), with the unfortunate result that much of what you can still find today in popular web articles concerning rudists, including that in Wikipedia, has more to do with science fiction than with science.

The revised conceptual model of rudist palaeoecology makes better sense, too, in view of the greenhouse climatic context in which Cretaceous carbonate platforms developed. For a start, because of the relatively high global sea levels of the time, flooding large parts of the continents, many of these platforms developed within shallow epeiric seas, where shedding of their bioclastic sediments led to extensive progradation on low angle clinoforms. The latter process gave little opportunity for the establishment of fixed rims, in contrast to the steep ocean-facing slopes of most tropical reefs today. Moreover, the relatively small amplitudes of climatically induced sea-level oscillation forced by periodic orbital variations, compared with those of icehouse regimes, left a legacy of predominantly flat antecedent surfaces on the platforms, with little erosive topography (except where tectonically uplifted); and the limited accommodation space provided by each minor sea-level rise restricted aggradational growth, causing most of the skeletal production to be laterally re-distributed by currents in banks of bioclastic sand and debris (e.g. Fig. 4c, d; see also Simone *et al.* 2003), smeared across the platform tops.

Hence, in contrast to modern reef-rimmed platforms, the greenhouse depositional context of the Cretaceous favoured the development of unrimmed, flat-topped platforms with layer-cake bedding and gently steepening distal slopes (Skelton 2003), except where tectonically disrupted. Accordingly, the rudists thrived on them as opportunistic sediment-dwellers, forming laterally extensive shelly 'meadows' or low mounds of limited relief relative to surrounding substrates, and frequently of low species diversity, in marked contrast to today's reef framework-builders (Gili *et al.* 1995). Corals, meanwhile, far from declining, as supposed by the competitive displacement hypothesis, in fact also diversified, though mostly — again — as sediment-dwelling forms (Rosen and Turnšek 1989; Rosen *et al.* 2002).

In conclusion, while global conditions in the Cretaceous allowed an acme of carbonate platform development, they were generally inimical to the development of reefs like those of today in terms of relief, growth fabrics, facies distributions, biological diversity and many other linked ecological aspects. Hence, uncritical modelling of rudist facies on patterns shown by modern reefs risks both academic and applied (e.g. petroleum geological) misinformation.

Nifty ways for acquiring large data sets

A final topic for brief consideration is how the large amounts of primary data that fuel virtual representations in evolutionary science can be collected in the first place. In some cases, high-tech automated methods of data-acquisition have come to the rescue, as, for example, with modern DNA-sequencing for the assessment of evolutionary relationships, mentioned earlier. In other cases, though, there is no better alternative to large numbers of straightforward observations being uploaded to data-gathering websites by lots of motivated people — i.e. 'citizen science'. Some successful UK examples with large followings include The Woodland Trust's 'Nature's Calendar' for tracking year-on-year changes in biotic seasonal signals (http://www.naturescalendar.org.uk/), The RSPB's 'Big Garden Birdwatch (http://www.rspb.org.uk/birdwatch/), and from nearer to home, of course, the 'Evolution Megalab' (http://www.evolutionmegalab.org/ ; see also Worthington *et al.* 2011 and Fig. 1) and 'iSpot' (http://www.ispot.org.uk/). Such web-based enterprises mean that huge numbers of enthusiasts can now contribute to significant science (e.g. Silvertown *et al.* 2011, for the Evolution Megalab) every bit as valid as that produced by expert elites such as those running the giant hadron collider or multi-billion dollar satellites (and quite a lot more cheaply, too!).

Conclusion

Crucial to the scientific eligibility of a hypothesis is its testability by reference to empirical evidence. In simple cases, the requisite evidence may comprise just direct observations of real objects, but in many instances virtual patterns abstracted from large numbers of observations provide the most pertinent evidence, as illustrated here with respect to a number of examples from evolutionary science. Such evidence is thus hierarchical in nature, involving both primary, or 'real' data, and virtual representations derived from them. The latter may prove misleading, however, if compilation of the primary data is subject to systematic technical or conceptual errors. Hence one should never lose sight of possible inconsistencies or qualifications thrown up by primary observation, which may indeed open the way to better scientific explanations (a point surely just as true for learning about science — to return to the opening sentence of this essay — as it is for scientific discovery itself).

Advances in methods both for gathering and processing large amounts of data have vastly expanded the scope of virtual forms of evidence. Although many such developments now rely upon elaborate automated methods of data-collection, there are still plenty of scientific questions for which website-based harvesting of simple observations uploaded by enthusiasts ('citizen science') remains the most practical option. So the future of science is certainly not limited to the activities of white-coated boffins in expensive labs. Given the need for sound scientific understanding of some of the major problems that we face today, such as climate change, science education therefore needs to remain as open and encouraging as possible to all who wish to engage with it. Faced with uncertain future, failure to learn how to understand is our worst enemy.

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Archaeopteryx: new views of an iconic fossil

Dr Dee Edwards

OUGS President 1997–1998

Abstract only

Only 11 specimens of Archaeopteryx are known. Some are relatively complete, but others are merely fragments. They have all been found in relatively small areas of Bavaria, southern Germany, close to the towns of Solnhofen and Eichstätt. All were discovered during the quarrying of late Jurassic 'lithographic limestone', which formed a Lagerstätte that preserved many marine creatures in perfect detail.

This talk briefly traced the timeline of the discoveries of Archaeopteryx, from the first in 1861 (now known as the 'London specimen' because it was bought by the British Museum and now resides in the London Natural History Museum), through to the spectacular tenth specimen (the 'Thermopolis') 're-found' in 2005. There is an eleventh specimen, announced in 2011, but this has not yet been described scientifically or been given a name.

Dr Edwards' talk introduced the use of a new, non-destructive technique of photography in UV light that has been developed by a friend, Dr Helmut Tischlinger of Stammham, Bavaria and that gives fascinating new insights into the structure and biology of these animals.

Rescue palaeontology

Dr Dave Williams

OUGS President 1991–1992

Abstract only

The Open University has always used replicas for teaching about fossils; how else to provide a thousand students each year with the 'same' hand specimens for study at home? When The OU started in the early 1970s, these replicas were made by Stuart Baldwin in a small cottage industry. The fossils for the Level 2 Geology course were chosen from museums by Simon Conway Morris and Peter Skelton in the mid-1980s, and many are still in use today. Later, the replica-making business came to The OU, to ensure supplies for courses. On retirement, Dee Edwards and I bought the business from The OU and moved to Cornwall.

Recently we have been asked by Natural England and others to use the same methods of moulding and casting to replicate large fossiliferous outcrops. Many fossil-bearing sites in the UK have been badly defaced by 200 years of collecting. Making replicas of what is left today is part of geoconservation. We call this process 'rescue palaeontology'. We have worked on dinosaur tracks from the Yorkshire coast, arthropod tracks in Fife, pre-Cambrian strata near Leicester and even down a Wenlock Limestone mine at Dudley.

Large meteorite impacts on Earth: more than just a hole in the ground

Prof. Simon Kelley

Isotope Geochemistry and Head of Earth and Environmental Sciences 2004–2007
Director of the University research centre CEPSAR

Abstract only

Meteorite impacts get a bad press. Most of what we hear about them is the mass extinctions and death of dinosaurs. Well, OK, so maybe there is a bit of a correlation between [meteorite] impacts and mass extinctions, but it's not as strong as the correlation with large volcanic provinces — now those are the real bad boys of the extinction world! What I'd like to explore in this talk is that correlation with sudden environmental change [and mass extinctions], but also what we've learned recently about sudden climate change from a sediment core in the Boltysh meteorite impact crater in the Ukraine.

The core [of this crater] represents a unique record of changing climate from more than 65 million years ago, at a resolution that we can normally only achieve for very recent climate change in modern lake sediments; so [the analysis of this core is] helping us to learn a lot more about the short-term climate change [that occurred] just after the end of the Cretaceous Period.

Book review

Smith, Alan 2012 *The Big Lakes of Lakeland* [Landscapes of Cumbria Number 5]. Keswick: Rigg Side Publications (ISBN 978-0-95446-794-4; paperback, 104pp; £6.99)

This is the fifth book by Dr Alan Smith in this bijou collection of guides to various aspects of Cumbrian geology and geography and, with 104 pages, much more substantial than his other books in this series. It comes in a handy, A5 format and is an accessible and useful guidebook.

He gives a brief description of the underlying geology of the Lake District and then shows how it affects the disposition, structure and shape of the various Big Lakes.

The text is lavishly illustrated by many photographs and very clear, simple maps. There are 104 figures (photos and maps) in all.

The statistics of the 17 major lakes are all there, as well as a little of the history of early surveys. The geomorphological processes by which the lakes were formed during the ice age are well explained followed by detailed descriptions of each lake.

I am delighted to add this to my collection of Lake District guide books — lovely to dip into, with some fascinating data. I didn't know until now that four of the islands in Derwent Water are in fact drumlins left behind from the last glaciation, while others are rocky outcrops of the Skiddaw group; nor that the whole valley is fault controlled by the Derwent Water Fault and excavated by ice into the relatively weak Skiddaw Group rocks, with a dolerite dyke forming the promentary of Friar's Crag, while other resistant volcanic rocks produce the crags along the eastern margin (Falcon Crag, Shepherd's Crag, Ashness Fell and others).

This guidebook is rather more geomorphological in content than geological, but is absolutely fascinating nevertheless — and a good buy at £6.99.

— Mary Howie, OUGS

Book review

White, William H. 2013 *Geochemistry*. Oxford: Wiley-Blackwell (ISBN 978-0-47065-668-6; paperback, 660pp; £37.50; ISBN 978-0-47065-667-9; hardback, 660pp; £75)

I have a recurring fantasy that if I were 50 years younger I would be just triumphantly receiving a PhD for some great thesis in geochemistry — something that would determine the rate of orogeny for a mountain belt, or whether certain basalts were MORB, IAB, OIB. Hopefully at that tender age I would be capable of handling this great tome, which weighs about 3½ lbs (sorry, I would be thinking metrically, of course. There's a useful list of SI units and conversions in a short appendix, as well as of physical and chemical constants, and the chief measurements of the Earth and the Sun). If I were in that position, I can well imagine this great work becoming my Bible, the summation of the life's work of one of the professors in the Department of Earth and Atmospheric Sciences at Cornell University, who got his own PhD as long ago as 1977, and who has been founding editor of the electronic journal *Geochemistry, Geophysics, Geosystems* and currently serves as chairman of the EarthChem Advisory Committee (an international geochemical database initiative).

It is not surprising that from such a background this work should be comprehensive. As the publishers' blurb says, "The book first lays out the 'geochemical toolbox': the basic principles and techniques of modern geochemistry, beginning with a review of thermodynamics and kinetics as they apply to the Earth and its environs. These basic concepts are then applied to understanding processes in aqueous systems and the behavior of trace elements in magmatic systems. Subsequent chapters introduce radiogenic and stable isotope geochemistry and illustrate their application to such diverse topics as determining geologic time, ancient climates, and the diets of prehistoric peoples. The focus then broadens to the formation of the solar system, the Earth, and the elements themselves. Then the composition of the Earth itself becomes the topic, examining the composition of the core, the mantle, and the crust and exploring how this structure originated. A final chapter covers organic chemistry, including the origin of fossil fuels and the carbon cycle's role in controlling Earth's climate, both in the geologic past and the rapidly changing present."

I can't agree with their claim that "*Geochemistry* is essential reading for all earth science students" — it is far too detailed for OU undergraduates or interested graduates. For researchers and applied scientists I can imagine that it has just about everything they could want, and it is fascinating to see the range of applications of geochemistry in all the branches of earth and environmental sciences. Additional resources can be found at: www.wiley.com/go/white/geochemistry; these include PowerPoints of all figures from the book for downloading; PDFs of tables from the book; and "Instructor Resources for Chapter Exercises" (each chapter has up to 20 problems at the end for serious students to work through, like SAQs — but with no answers)!

— Philip Clark, MA Oxon, BSc Open

Geoconservation in Bucks — interesting rocks on your doorstep

Dr Jill Eyers

BA (Hons) PhD PGC (TLHE) (Open)

[Editor's note: Dr Eyers stepped in and presented this talk when Prof. Tony Grindrod, scheduled to speak, was unfortunately held up in an airport abroad and therefore unable to make it to the Symposium. Fortunately, however, Prof. Grindrod was able to come to the April 2013 OUGS AGM and deliver his lecture at that event. We hope to publish his paper on 'The Earth's physical resources at The Open University' in OUGSJ ***34*** *(2).*

On behalf of all OUGS members I would like to thank Dr Eyers for her excellent talk and paper, and to Prof. Grindrod for rescheduling and attending our AGM to deliver his paper.]

Introduction

Buckinghamshire is not necessarily renowned for its geological exposures. It is perhaps better known for its rolling Chiltern Hills, the flat-lying Aylesbury Vale and built environments such as Milton Keynes. However, it has had a rich industrial past, exploiting geology as varied as Jurassic and Tertiary clays for brick-making, Quaternary gravels, Chalk and even phosphate deposits for agriculture. In addition, there is the landscape itself — geomorphology is evident in a multitude of landforms and features. Although this presentation focuses on Buckinghamshire — the principles are the same for every single county and region of the British Isles.

Why is geoconservation important? Basically, geoconservation is the conservation of geodiversity — making available places where the vast range of rocks, minerals, fossils, geomorphology and soil features can be seen, researched and celebrated. It underpins everything else the British Isles has to offer. For instance, geology makes the landscape we walk or live on, it provides the soils we grow our food on, and is vital for the character of our woodland and nature reserves — because ecosystems are influenced by the local geology. Geology provides water sources and natural environments both for people and wildlife, but it also provides industrial materials such as gravels, sands, stone, metal ores or other resources.

Geoconservation is therefore the conservation of this wide variety of geology with its links to other heritage areas: natural history, archaeology and industrial history, among many others. Conservation of earth science sites, be they rock outcrops, natural landscape or historical sites, is important for several reasons:

- to preserve our geological record for the future;
- to train future geologists and geographers;
- to provide an essential teaching ground for schools and universities;
- to provide material for future research;
- to provide sites for a rapidly developing leisure industry;
- to preserve geological sites which also have historical, archaeological, cultural or wildlife value.

Site selection should reflect these differing needs, and the job of selection falls to county-based 'RIGS' groups and the sites become known as RIGS sites (Regionally Important Geological and Geomorphological Sites). Some counties still call these RIGS, but they are generally now called Local Geology Sites (LGS). The latter, shorter, name is more public-friendly and links better to the local biological equivalent. This last point is very important, as it is one thing to place a label on a site and say "this site is important", but in reality how do you go on to protect it from, say, housing development or becoming a landfill site? The only way is to make sure that, once designated and like their fellow Local Biological Sites, they get onto the Planning Department's database. Once on this database a flag is raised when any potential process threatens to cause it damage or to otherwise affect it. In this way there is added conservation protection from the Local Authorities.

Buckinghamshire, like every part of the British Isles, has success stories and disasters in geological conservation. The following examples will show some of the fascinating geology of Bucks while illustrating the process of geoconservation and highlighting some of the problems.

Figure 1 The Blue Lagoon Nature Reserve — once a thriving extraction industry for the top-quality Fletton brick known as the 'Bucks multi'.

The Bucks multi's are no more

Newton Longville Brick Pit was once a thriving extraction site for the Oxford Clay, yielding a fascinating insight into the stratigraphy and history of life through the many fossils found there. The Oxford Clay runs in a north-east to south-west trending belt from South Yorkshire, through Cambridgeshire, Bedfordshire, across northern Buckinghamshire, extending down to Dorset.

In north Buckinghamshire the belt runs between the towns of Buckingham and Aylesbury and, where not covered by ice-age deposits, outcrops discontinuously as a heavy clay soil. The Oxford Clay is divided into units of the uppermost calcareous mudstones of the Weymouth Member (old classification — Upper Oxford Clay), the Stewartby Member (Middle Oxford Clay) and the underlying fossil and organic-rich mudstone, the Peterborough Member (Lower Oxford Clay). The high organic (carbon) content of the Peterborough Member made

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it particularly suitable for brick-making because it reduced the amount of external fuel required to fire bricks and therefore lowered the cost of firing. Exploitation of the Oxford clay lead to the Fletton process of brick-making, which in turn enabled brick manufacture on an industrial scale. Consequently much of the rapidly expanding city of London in the late 1800s was built with the Fletton stock brick from this area.

One of the main quarries is now the Blue Lagoon Nature Reserve (Fig. 1, *previous page*). But there is not a sign of the past industry or an exposure or any fossil remains — representing a lost opportunity for local people, schools and geologists alike.

Sites fit for the future?

The Buckinghamshire County Museum archive photograph (Fig. 2) shows a worker at the Denner Hill sarsen extraction site in 1898. The stone was worked for setts, which may be seen throughout town centres in south Bucks. Sarsen is a calcrete formed in semi-arid conditions such as those found in the modern-day central Australian desert. However, the rock has become broken and moved due to the affects of the last Ice Age. Although sarsens occur throughout Herts, Cambs, Beds, Bucks, Berks, Oxfordshire and Hampshire, along with other counties, the reports of *in situ* stone is exceptionally rare.

The author is aware of only one possible *in situ* location exposed today. The age of this intriguing rock is still in dispute, so any sarsen found *in situ* today may unlock the key to where it lies within the stratigraphy of the Tertiary. The rock in Figure 2 seems to be *in situ* and might reveal a stratigraphic age — except for the fact that the site was backfilled many decades ago. However, the value of photography is clear here — note the rounded, globular shape of the sarsen, plus it seems to be an isolated block. Also note the pebble bed in the surrounding sediment at the upper surface level. These all provide clues as to formation of sarsen as a silcrete within an alluvial system, which subsequently becomes a soil horizon.

More *in situ* sites are needed to examine with modern techniques . Conserving sites of special interest, such as this one and also the LGS at Bradenham (Fig. 3), would reward future researchers as science moves forward and new ideas can be applied to old rocks.

Figure 2 Denner Hill, near High Wycombe 1898 — the site of large quantities of sarsen stone, now backfilled (© Buckinghamshire County Museum archive collection).

Figure 3 Sarsen stone, not in situ*, in a dry valley at Bradenham, Bucks, moved by solifluction during the last Ice Age. However, it is valuable as proof of the alluvial nature of this rock — note the pebbly base deposited during high-energy flow, which fines upwards into a sandy upper unit.*

Quaternary sites

It is not the intention of this paper to showcase the whole of Bucks geology (spanning the Middle Jurassic to the Quaternary), but to reveal something of the importance of geoconservation. The Quaternary is a good case study to use for this purpose, as it shows the huge potential of looking for geology. The initial geological surveys followed by a rigorous audit proved that there is a wide range of lithology, sedimentary structures, fossil and research potential. These features proved to be from an extensive range of environments. Bucks became a 'little jewel' for the Quaternary. It is much overlooked in favour of the more 'showy', larger and often easier to access sedimentary exposures of this age in other counties, particularly those at the coast. In terms of environments represented by the Quaternary of Bucks there are good examples of:

- till deposits
- glaciofluvial deposits
- glaciolacustrine deposits
- englacial streams?
- eskers
- ice wedges, cryoturbation & other periglacial features
- interglacial sediments and faunas
- dry valleys & coomb deposits
- evidence of major down-cutting and diversion of rivers

This list is the very 'stuff' of geological research and may well surprise even those already interested in the Quaternary. Selecting just two examples — the till and the gravels of the proto-River Thames illustrates a tiny fraction of what can be seen in sediments of this county.

The till of Buckingham Sand Pit is the only evidence we have of an ice sheet passing down the Vale of Aylesbury during the Anglian glaciation around half a million years ago (Fig. 4, *opposite*). This is not just direct evidence of ice sheets, but the clasts it contains are direct evidence for what geology the ice passed over. The evidence provided is of local chalk and Jurassic limestone, but also for reworked Bunter pebbles and ironstone from

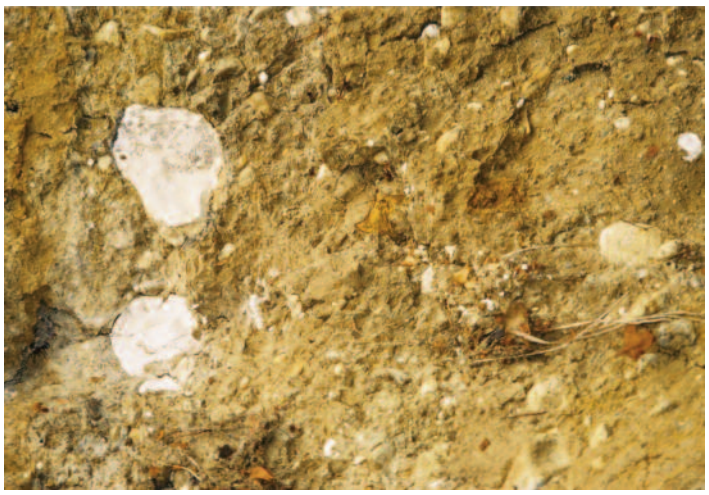


Figure 4 Till exposed in the LGS site at Buckingham Sand Pit, a town location that has also become a haven for wildlife in an otherwise sterile urban area. Geological and ecological conservation may work hand in hand.

farther afield (reworked from older river deposits).The Buckinghamshire till even contains gabbros from Scandinavia! This deposit can be compared to that exposed in cliffs on the north-east Norfolk coastline, where it can be seen to be very different indeed.

Tracing the story of the Anglian ice it becomes clear that there are cold-based phases (when ice freezes to bedrock and plucks it up) and warm-based phases (when rock is crushed and plastered to the frozen ground as the ice sheet glides over a wet, lubricated surface. Buckingham sand pit represents a later warm-based phase as it begins to melt at the end of the glaciation (known as melt-out till).

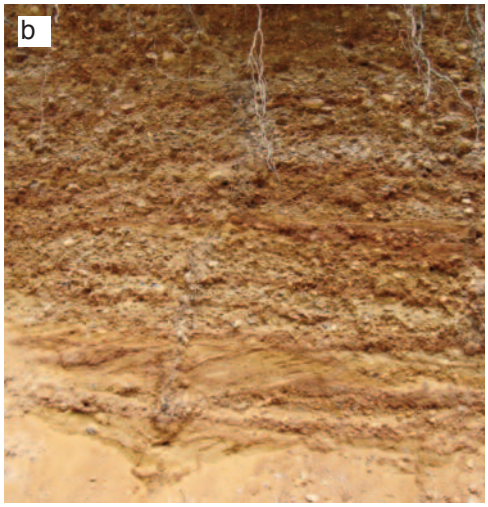
River diversion

Only by having geological exposures available for viewing can we train our future geologists, undertake new research or help the general public appreciate our heritage. Anglian ice had a major role in the re-routing of the River Thames. Before Anglian ice moved across Britain the River Thames flowed from a source area north of Birmingham and on reaching Oxfordshire it turned eastward, flowing across East Anglia and out into the North Sea near Ipswich. With the arrival of the Anglian ice sheet about half a million years ago (MIS13), water became locked up in the glacial or tundra environments. On the thaw and retreat of the ice, the rejuvenated waters of the Thames found the old river valley still blocked by ice, hence a new valley was cut — thus making the 'gaps', for example the Goring Gap. On route there was a little ponding for a short while near the Burnham Beeches quarry site (Fig. 5), but finally the Thames forged a new valley and a new route that we know today as the Thames Valley leading through London and thus out to sea.

Battle for 'possession'

Some sites, such as College Lake, had a long history of extraction, providing many years of excellent exposure. This site shows three important interests: the boundary between the Lower and Upper Chalk, evidence for tundra conditions of the Devensian (such as ice wedges and cryoturbation) and also a rare outcrop of the sands and gravels of the Ipswichian Interglacial (protected as an SSSI — Site of Special Scientific Interest) (Fig. 6).

Figure 5a and 5b: A small site in Burnham Beeches Park showing evidence for the diversion of the Thames by the Anglian ice. An amazing story contained in a couple of metres of sands and gravels.



Despite its very powerful geological story geologists are a rare species to be seen on this BBOWT site — mainly as it has a prime focus for birds and bird habitats. This now presents a clash of interests as the design for wildlife never took the interests of the geological community as part of the long-term management plan. The result is that exposures are not accessible or people are

Figure 6 College Lake Nature Reserve, Pitstone, central Bucks — chalk, tundra and the Ipswichian Interglacial all on one site.

Figure 7 Coombs Quarry, Coombs near Buckingham. Middle Jurassic limestone (the Blisworth Limestone) has been extracted from this area from at least the 14th century, maybe a lot earlier. However, by the time it was viewed in the 1990s it was largely overgrown, having been in disuse for almost 100 years. This is the site before conservation work.

Figure 8 Coombs Quarry after the conservation work and a JCB had been active. Low-angle walkways with guide-rails make safe access for all visitors, and a pile of replenished rock makes easy fossil hunting and viewing of the lithology. Visitors may hammer the loose rock in the rock pile (with the normal precautions), but are requested not to hammer the quarry faces — for the sake of the integrity of the exposure and for their own safety.

banned from accessing them, while other accessible exposures are allowed to overgrow. This highlights the need to liaise with land owners and managers at an early stage of any site's development. It is essential to express the geological interest so that it can be acknowledged and the links it has with the associated wildlife celebrated and enjoyed.

Geoconservation in action at Coombs

One of Buckinghamshire's flagship sites is Coombs Quarry. It is used regularly now for many geology groups, for teaching OU students and school children, and for local general public events also. However, without the foresight of the Bucks Earth Heritage Group the geology would never have been made available to view and enjoy. With funds from the National Lottery and a good deal of help from the owners (Bucks County Council) the derelict area (Fig. 7) was transformed to a pleasant and safe geological site (Fig. 8), which has now gone on to become home to a wealth of wildlife, including some locally rare species (Fig. 9 a–d).

For Britain to continue to have a geological heritage with which to tell these 'stories in stone' — without which we will be unable to train future geologists or to undertake future research — all counties should undertake a geological audit and ensure that the best sites are designated as Local Geological Sites (Fig. 10, *opposite*). This information should then be lodged with the Local Authority. If that audit has already been done, such as for Buckinghamshire, then site monitoring with the ability to work on and look after sites with volunteers is essential in maintaining that geological interest — along with all its associated other interests. This is the only way forward to protecting our heritage.

The contact details for the Buckinghamshire conservation group (Bucks Earth Heritage Group) is Mike Palmer, BEHG, Museum Resource Centre, Halton, Bucks, HP22 5PN. It is well worth becoming a member to help the group funds and to receive a wealth of geological information, training and advice.

Their website can be found at www.bucksgeology.org.uk

Figure 9 Some of the locally rare species at Coombs Quarry: (a) a bracket fungus; (b) the leopard slug; (c) the yellow archangel; and (d) the brown long-eared bat.

Figure 10 Cliveden cave: phosphatic Chalk at the top of the Chalk cliffs at Cliveden House, carved by solution when the river Thames was much higher, it comes complete with its resident gnome!

Volcanology and the contribution of citizen scientists

Prof. Hazel Rymer
Prof. of Environmental Volcanology, The Open University

Abstract only
In order to understand the mechanisms of [volcanic] eruption triggering and, just as important, eruption cessation, long-term geophysical studies are needed. Such studies are often quite routine measurements, but they need to be made carefully and they need to be made over very long time periods. OU students have contributed to the collection, and in some cases analysis, of geophysical data amassed over a period of almost 35 years at active volcanoes in Central America, Italy and Iceland. Here [in her lecture] we present the results and a summary of the state of our understanding of the dynamics of some persistently active volcanoes and calderas in a state of unrest.

Book review

Etches, Steve, and Clarke, Jane 2010 *Life in Jurassic Seas — the Autobiography of a Fossil Collector*. Chandler's Ford: Ashfield Books (first printing paid for by the Geological Association; second printing paid for privately). (No ISBN; card cover, 378pp with monochrome illustrations; £10 + £2.50p&p — available from Mrs Jane Clarke, Ashfield Books, 65 Oakmount Road, Chandler's Ford, Hampshire, SO53 2LJ; tel 023 8025 2309; e-mail jbclarke@ntlworld.com)

Summary from the back cover:

> "*Life in Jurassic Seas* is aimed at a wide readership from professional palaeontologists, through amateur fossil collectors to curious beachcombers. Steve's story tells how, with tenacity, single-mindedness and focus, he turned himself from a curious fossil collector into an internationally recognised expert on fossils from the Kimmeridge Clay. Readers with an interest in personal achievement, despite the odds, will enjoy the first few chapters, which chronicle Steve's progress. Those more interested in the fossils themselves will be drawn to the sections on his collection and the 141 plates of illustrations, each specimen assigned its scientific name where possible. However, some of the specimens are unique and further research is necessary to establish their identity: some will be new to science."

Steve Etches details his progress from a curious small boy collecting everything, through extra-mural studies and local groups, to being rated as an expert on the Kimmeridge Clay fossils — having once been told no fossils had been found in the formation. We learn of his endeavours at cleaning his finds, the tools and methods used and some of his disasters. Throughout the biographical section — up to page 116 — his enthusiasm and growing experience is apparent. He was not afraid to ask for help from experts and establishments, despite the attitude of some academics. He is very willing to share his knowledge and collection with others, but understandably reluctant to lend specimens because of some misfortunes. He acknowledges the help and encouragement given by Jane and Trevor Clarke, as well as by other people.

He is still adding to the collection, working not only in Dorset, but wherever the formation outcrops, including European sites and Scotland. His work has been acknowledged by both the Palaeontological Association (1993) and the Geological Association (the RH Worth prize for 1994).

The section from page 117 to 365 comprises the fossil guide, followed by acknowledgements, glossary, bibliography and index.

The fossil guide is based on a catalogue of Steve's collection and consists of seven sections of photographs, each of which is preceded by Jane Clarke's very clear drawings, providing the environment and samples of the animals included, as they may have been in life.

For each specimen there is a scale bar and a catalogue number; on the facing page, below the classification guide, there is a brief comment on some items.

The seven sections are on the phyla: Mollusca, Arthropoda, Brachiopoda, Echinodermata, Pisces, Reptilia, and a miscellany including trace fossils, plants, insects, corals and coprolites.

This book would be a useful addition to the library of any person interested in fossils of this specific formation and also a reference work helping to name a find not easily identifiable with a basic guide. Because the photographed specimens are not all perfect, the helpful description of — perhaps — a "squashed skull on its side", could help decide the find's possible identity. Its stout card cover and A5 format makes it just right to include in one's day sack.

— Rosemary Darby, BSc (Hons) Open–Natural Sciences with Earth Science, BA Open, Certs Ed (UK & NZ)

Volcanoes, earthquakes and tsunamis in the media

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Introduction

When a newsworthy volcanic eruption, an earthquake or a tsunami happens, the news media are usually anxious for expert comment. This is not because their correspondent can't get the basic facts (where, when, how big?) easily enough these days — after all they have access to the same Internet sources as you or I. However, they like to flesh out a story. To make it different from their competitors' coverage they usually prefer to include some quotes (for print or online news) or an interview (for radio or TV). This provides opportunities for UK scientists to show the depth of expertise that we have in this country, while at the same time helping journalists to 'get the science right'.

I wrote The Open University's level 1 science short module S186 *Volcanoes, Earthquakes and Tsunamis* (using my Teach Yourself Book of the same name, Rothery 2010) and have been chairing it since its first presentation in 2007. Among this trio of natural hazards, my own research has been in volcanology alone, but I have found that my knowledge is sufficient to answer most journalists' queries, or to locate the answer without too much bother. The way I look at it is that if I'm not competent to talk to a journalist about such things, then I had no business writing an Open University module about them either!

How the media operate

I became involved with answering journalists' queries gradually, beginning back in the 1990s. For example, a print or broadcast journalist would phone The Open University seeking advice about a new eruption of Etna, and sometimes the call would be put through to me. Provide usable quotes often enough and journalists start phoning you directly, or (these days) messaging via Twitter or Facebook. The OU has a pretty good reputation for being able to provide useful comment in many areas, so journalists also make approaches via The OU's Media Relations Unit, who will then pass the query on to an appropriate academic.

There is also an admirable national organisation called the Science Media Centre (www.sciencemediacentre.org), which functions as a press office when science hits the headlines. It is funded by donations from industry and scientific bodies, and maintains its independence by capping donations from any one source at 5% of its annual running costs. When a big story breaks, the SMC will put out a call to its known expert contacts, asking for comments, which it compiles and then e-mails to journalists as a 'press release' in the following fashion:

Expert reaction to today's earthquake in Shakeyville

Schools and hospitals are among many buildings destroyed in an earthquake in the Shakeyville region overnight.

Dr James Hutton a lecturer in geology at Oxbridge University said: "The magnitude 6 earthquake that has just struck Shakeyville was not especially big, but it happened at a shallow depth right below the city and so the ground-shaking was particularly strong. Earthquakes are common in the Shakeyville region, because it occurs close to a fault where the China plate slides past the Porcelain plate at an average rate of 4cm per year."

Prof. Anne Eggspurt, professor of mechanical engineering at Redbrick University said: "Damage to Shakeyville appears to be confined to older structures, built before current designs for earthquake-resilient structures had been developed. These typically add about 15% to constriction costs. Retrofitting existing buildings is more expensive, and the mayor of Shakeyville is on record as saying that he does not have the budget to enforce standards on civic properties."

You will see that my hypothetical Dr Hutton and Prof. Eggspurt each gave short and clear statements, which a print or online journalist could easily 'mine' for a quotation, and which could help a broadcast journalist choose whom best to try to get an interview with.

Print journalists often phone with specific questions to probe more deeply into what an expert has said in their comment. However, sometimes they choose to embed quotes from a SMC press release within their story. When this happens to me I am unaware of all the places where I'm going to be quoted, although The OU subscribes to a bureau service that collates all mentions of The OU in the media, so I usually find out eventually. Incidentally, even when a print journalist has spoken with me, their deadlines usually preclude them from sending me a draft of their article for comment or correction.

When I have been quizzed by a journalist who asks something specialised that is beyond my field of expertise I will try to be clear that I am outside my comfort zone and then give them my best guess, accompanied by a recommendation that they should try to ask someone else as well. I have rarely, if ever, ended up being embarrassingly (mis)quoted as a result of being frank with a journalist.

A live interview for radio or TV is different. These are invariably set up in an approach from an aide or researcher, rather than by the actual interviewer. Radio interviews can be done by telephone, though The OU has a couple of sound-proofed rooms with 'ISDN' lines that give higher quality. For a TV interview they either send a camera to you, or ask you to travel to the studio where sometimes you are faced with a remotely-operated camera and an interviewer in a different continent. For example, *Al Jazeera* fronts most of its English-language rolling news programme from Doha (Saudi Arabia), and has a presenter on duty in its London studio only part of the time.

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There is no rehearsal for radio or TV, and rarely even a chance for any prior off-air chat with the interviewer to establish what best to talk about, though that may have been partly covered in whatever conversation has taken place during the initial approach. If asked an unanswerable (or dumb) question, I have found that good options are either to say, "we just don't know", and then explain why (in the case of something that probably nobody knows), or act like a politician by answering a slightly different question than the one that was asked. Broadcast media want something engaging to fill two or three minutes, and don't need you to follow a rigid agenda.

Case studies

If I hear news of a damaging earthquake, I will usually go straight to the United States Geological Survey earthquake hazards website (http://earthquake.usgs.gov/) to find out the basic facts, and then email a quote to the SMC without waiting to be asked. A typical example was 27 February 2010, when I woke up to radio news headlines of a very large and shallow earthquake offshore of Chile. Clearly it had potential to cause a major tsunami. As I soon discovered, reports were already coming in of tsunami damage in Chile. The unknown factor was how big the waves would be when they reached other parts of the Pacific Ocean. Here is my contribution to the compilation of expert comment issued by the SMC — a real life version of my fictitious Shakeyville example:

Expert reaction to the earthquake in Chile

Chile has been struck by one of the most powerful earthquakes in the country's history, causing over 700 deaths so far and forcing many others out of their homes.

Dr David Rothery, Dept of Earth & Environmental Sciences, The Open University, said:

"This morning's (06:34) magnitude 8.8 earthquake close to the Chilean coast has caused a tsunami that is now radiating away from the epicentre and travelling at several hundred km per hour across the Pacific ocean. The first waves are expected at Hawaii at 11:19 Hawaii Standard Time but are also travelling along the S America coast and will reach Colombia and Costa Rica after 1300 GMT (see http://www.prh.noaa.gov/ptwc/). Some earthquake damage is to be expected ashore in Chile near the town of Concepcion.

"A magnitude 8 quake is a rare event. On average there is only about one of these per year, globally. This one was caused by the floor of the Pacific ocean being pushed below South America. Because the epicentre was under the sea, the sudden jerking of the sea-floor displaced water and triggered a tsunami. The focus of this quake was at a depth of about 34 km — which is relatively shallow (and hence damaging) though not quite so shallow as the magnitude 9.1 quake in the Sunda Trench that caused the 26 Dec 2004 Indian Ocean Tsunami."

You can find the original SMC press release here http://www.sciencemediacentre.org/expert-reaction-to-the-earthquake-in-chile/-2-2/ — which has comment from six experts, even though it was a Saturday. That one got me on the Channel 4 evening news, during which a wide camera-angle,

Figure 1 Channel 4 News 27 February 2010. Krishnan Guru–Murthy attempts the well-known subduction zone hand gesture.

which I had not anticipated, revealed my mismatched footwear because my right leg was in plaster (Fig. 1), causing consternation among friends who saw the broadcast, but who had been unaware of my accident. On this occasion the broadcaster provided a door-to-door taxi service for me.

My next significant media excursion began on 14 April 2010 with news of an earthquake in China's Qinghai Province, which had clearly claimed hundreds of lives. The media were more than usually interested in this because the far more disastrous May 2008 Sichuan earthquake was still a fresh memory, and they wanted to know if the one had caused the other. You can find my SMC statement here http://www.sciencemediacentre.org/expert-reaction-to-qinghai-earthquake-2-2/ .

Unusually, in this example I was the only person who had provided comment by the time that the SMC felt they needed to disseminate it. As a result of this I was contacted by the BBC and helped with their website story (http://news.bbc.co.uk/1/hi/sci/tech/8620129.stm). I was answering related queries from newspaper journalists on the following day, when this tragedy was bumped from the headlines by a sudden change in eruption style at Eyjafjallajökull in Iceland. Here, what had begun as a photogenic but largely innocuous basalt eruption at the edge of an ice-cap (anticipated and tracked online by the current S186 students) switched location on 14 April to the subglacial caldera, whereupon it became explosive. The resultant 11km high ash column produced an ash cloud that the high-altitude winds blew our way, so that on Thursday 15 April airspace over the UK (and soon over much of Europe) was closed as a safety precaution. This turned into the biggest volcano story of the decade. Every volcanologist in the country was sought after, and because the initial airspace closure lasted for six days the story ran for a similar time. It came back into the headlines in May when the eruption re-intensified and sent another ash cloud over parts of Europe.

Eyjafjallajökull takes over

The SMC disseminated Eyjafjallajökull quotes from about a dozen experts, including me, on the morning of 15 April; see http://www.sciencemediacentre.org/expert-reaction-to-volcanic-eruption-in-iceland-2-2/ . I started getting calls from newspaper journalists about lunchtime, and by mid-afternoon I was in a taxi headed for BBC Television Centre to appear live on *Newsround*. While en route I had to turn down a request to appear simultaneously on *Al Jazeera* (which led to one of my

PhD students becoming *Al Jazeera*'s volcano expert for the duration), but accepted a request to rush out to Heathrow Airport after *Newsround* to cover the story as it unfolded for the BBC News channel.

That was in interesting evening. On an embankment looking across the Heathrow perimeter road there were a dozen camera crews, each with their own satellite vans, from a UK and overseas TV networks. I wish I'd had a camera with me! They had all chosen to cover this story on location, because the busiest airport in the world had been brought to a halt, and no planes were moving on the tarmac in the background. I was there from 7pm until 9.30pm, during which time I gave two live interviews, distinguished from the others occurring to either side in that I think I was the only person to have a sample of volcanic ash to show to the camera. This wasn't my idea; the *Newsround* researcher had asked me to bring some ash with me, and for the next week it travelled everywhere I did.

I was in demand for ITV *Lunchtime News* on the next day (Friday 16 April). Because I had an X-ray appointment, they sent a mobile crew to me and we did the interview live from the kerbside outside Northampton General Hospital (Fig. 2). An edited version was broadcast later in the day, and ITV News also placed a version on YouTube — http://www.youtube.com/watch?v=2mYHOuZfoJ4 — which I recommend if only to see the amazing disappearing car behind me, thanks to some unfortunate editing! At the weekend Sky TV interviewed me live from my home (Fig. 3) and in a pattern that was to become

Figure 3 Sky TV camera in my home, to cover the Eyjafjallajökull ash cloud over the weekend. On the windowsill behind me are my Volcanoes, Earthquakes and Tsunamis *book and The OU course — product placement of the kind that you can't do on the BBC. In a remote interview such as this, your only contact is via an earpiece. You can see neither your interviewer nor what pictures are being shown on air.*

Figure 2 ITV News van setting up on the streets of Northampton.

familiar, clips of me were spotted by friends stranded on various continents by ash cloud. This was when I first became aware that clips are liable to be taken from live interviews with ITV, Channel 4 or Sky and syndicated round the world. A former colleague of mine now based in France reported that he saw me dubbed into French.

The fuss carried on into the next week. Among my radio interviews was one for *Talk Sport*, with whom I'd never worked before. I had a joke ready about airborne volcanic ash, along the lines that I am a West Bromwich Albion supporter, so I am well aware that what goes up must come down, but although there was plenty of banter during interview I wasn't able to work it in. However, West Brom are *still* in the Premier League, long after the ash has come back down, so it wouldn't have been an appropriate analogy anyway.

One day I had to drive to a children's centre in Birmingham to rendezvous with a crew who had just finished covering a visit there by Gordon Brown (this was in the run up to the General Election). Mr Brown had left by the time I arrived, but several party workers were still there. "Ooh, are you a volcanologist? Wow! I'm more excited now than I was when I met Gordon." They posed for photographs with me, but I'm still waiting for my copies.

Funnily enough, when the eruption re-intensified in May and we were faced with a reimposition of airspace closures, a cameraman filming an interview with me had come directly from Chequers, where he had been covering David Cameron. There may be a moral there about the longevity of scientific vs political careers.

Throughout the crises, several questions kept recurring. Why is this eruption happening? How long will it last? Are the authorities right to close airspace? The first two gave me a chance to explain some volcanology (for example, what factors make an eruption explosive). For the third question I avoided being dragged beyond my field of competence by saying that the rules had been agreed in advance, and that it is a known fact that ingestion of ash in sufficient quantities does cause jet engines to fail.

Because I was consulting for *Bang Goes The Theory* (a BBC-OU co-production), I was able to assist in the scripting and design of a demonstration of the problem, broadcast on 27 April 2010, using some more of my volcanic ash as a prop. You can view that here: http://www.bbc.co.uk/programmes/p007gtm5.

What happened next

We've had more airspace closures since Eyjafjallajökull. An eruption of Merapi Indonesia (that did get me onto *Al Jazeera*) in November 2010, ash from Grimsvötn closing airspace in northern Britain in May 2011, and an eruption in Chile that closed airspace in south-east Australia in June 2011. The Grimsvötn event involved me in an interview for Radio 5 that I did over my mobile phone from a train somewhere between Crewe and Warrington while travelling north to reccie for the SXG288 hard rock fieldwork based at Blencathra. After I had arrived I did an interview for RTÉ (Irish radio)'s drivetime

Figure 4 Being wired for sound outside The OU's Berrill Building to comment on the Japan tsunami for ITV News.

Figure 5 Snatching a few moments online to catch up on the latest facts before interview at the BBC.

programme in which I had to respond to some ill-founded opinions voiced by the chief executive of Ryanair.

The 21 February 2011 Christchurch magnitude 6.3 earthquake was big news in the UK because it killed nearly 200 people in an English-speaking country. However, the only story that has come close to rivalling Eyjafjallajökull was the Friday 11 March 2011 magnitude 9.0 earthquake off the coast of Japan and its ensuing tsunami. Once again I contributed to a large SMC press release on the day http://www.sciencemediacentre.org/experts-comment-on-japan-earthquake-and-tsunami-2/ .

I was on ITV news outside The OU at lunchtime (Fig. 4, *opposite*) and found myself in the BBC news studios in the evening (Figs 5 and 6). The media demand for geoscientists rarely lasts longer than a day in the case of an earthquake or tsunami, but in this case because of the large number of dead and the unfolding situation at the Fukushima nuclear power station (damaged because the tsunami wall was not high enough, rather than by the earthquake) it ran through the weekend and into the following week.

Thanks to my previous lobbying, we had a *Bang Goes The Theory* feature about the Pacific Tsunami Warning Centre already 'in the can' and intended for an episode in early May. In light of events, the content of episode 1 of the new series (broadcast on Monday 14 March) was reshuffled to make space for this item, and Jem Stansfield worked through the weekend (with frequent phone calls to me) to devise demonstrations of stick-slip motion and of how a quake causes tsunami waves. This also made it into the programme and remains online as a teaching resource: http://www.bbc.co.uk/programmes/p00fnhvm.

On the Tuesday I found myself on *BBC Breakfast* to explain aftershocks and progressive rupture along an earthquake fault-plane, and to dispel worries about anything big enough to cause another tsunami, though I was bumped to a later slot by a nuclear reactor expert. Subsequently I was the first speaker at a press conference organised by the SMC, where my role was to reiterate what most of the journalists already realised — that it was the tsunami that had done most of the damage, and by now there was minimal risk of sufficiently large aftershock to trigger another tsunami — and to pass the baton on to the other five

Figure 6 About to go live on air with Kirsty Lang for BBC news to discuss the March 2011 Japan tsunami.

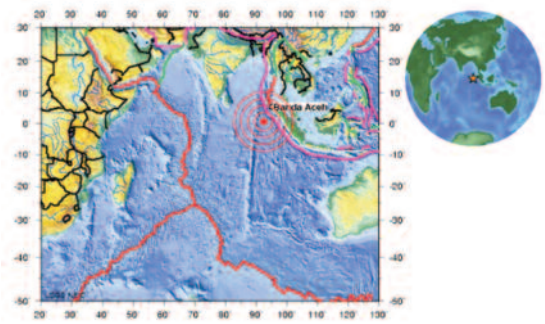

Figure 7 Epicentre location map for the 11 April 2012 Indian Ocean tsunami (courtesy of USGS).

panellists who were all professors of nuclear engineering or medical physics.

The biggest story of 2012 was triggered by a shallow magnitude 8.6 earthquake in the Indian Ocean offshore of Sumatra on 11 April 2012 (Fig. 7). At first sight, this looked frighteningly similar to the magnitude 9.1 source of the 26 December 2004 Indian Ocean tsunami, which claimed nearly 300,000 lives. My immediate reaction of "Oh no, here we go again!" was tempered by knowledge that now at least there was a tsunami warning system in place in the region. However, although close to the subduction zone, the epicentre was actually inside the Indian-Australian plate and so not on the subduction mega-thrust where a large shallow quake would very likely trigger a major tsunami. Even so, had this quake occurred at a normal fault, associated with bending of the plate as it approached the trench, there could have been a considerable up-down jerking of the ocean-floor, which would have triggered significant tsunami waves. Fortunately, it became clear after an hour or so that the fault rupture had taken the form of strike-slip displacement, so the ocean-floor must have been jerked sideways instead. By the time of my lunchtime interviews for ITV and Sky News (Figs 8 and 9) it was becoming clear that there was no major tsunami.

I was somewhat surprised to get a call from CNN during the afternoon, inviting me to appear in the first item on their 9pm current affairs programme. I explained that by then the event would all be over, and that in any case it was now clear that a major tsunami had not been triggered. "Yes, we know," they said, "we want you to explain *why* there was no tsunami this time. Oh, and please bring some blocks of wood or something to help you explain, because we like demonstrations with props." I agreed, but said that I'd find something more bendable than wooden blocks to show how subduction works.

This was the most fun interview that I've ever done. The anchor was Beccy Anderson, who has conducted one-on-one interviews with the likes of Benjamin Netanyahu, Ban Ki-Moon, Angelina Jolie and Tom Hanks. When I produced my props (Fig. 10, *opposite*) Beccy played along brilliantly, and even gave The Open University an extra name-check at the end. The interview is currently still viewable at http://www.dailymotion.com/video/xq2gdb_when-does-a-tsunami-generate_news — or at http://edition.cnn.com/video/#/video/world/2012/04/11/ctw-intv-dr-rothery-on-why-no-tsunami-generated.cnn .

Helping the news media with stories like these can be a distraction from the main job at times, and I have to be prepared to hop on a train to London at short notice (they provide a car between Euston and the studios), but it gets The Open

Figure 8 Preparing for Sky News interview in The OU Library about the 11 April 2011 Indian Ocean tsunami.

University's name in print or on the air, so it is regarded to be commercially worthwhile as well as being a 'good thing'. My Open University affiliation has never, so far as I am aware, been omitted from print or website reports. The *Sunday Times* misspelled my name once, but they are forgiven because they are among several media outlets that have kindly also awarded me the title of Professor, which The OU itself has yet to bestow upon me. On TV the presenter always introduces me as "from The Open University", and usually 'Open University' appears in the on-screen credit below my name (Fig. 11, *opposite*), especially if I remember to ask for this beforehand. My most amusing misattribution appeared on *Al Jazeera* on 22 October 2012. This was a three-way panel discussion about the verdict on the l'Aquila earthquake trial in Italy, in which scientists were found guilty of manslaughter on the grounds of inadequate communication of the risks. The programme was recorded at 4pm (before the verdict!) and transmitted about 6.30pm (after the verdict). Thanks to my mobile phone I was recruited for the programme about five hours in advance when I was out on my horse. The researcher asked me for some details about myself, so I told her that I chair The Open University's course (maybe I said module) on Volcanoes, Earthquakes and Tsunamis. Figure 12, *opposite* shows what they turned this into! (http://www.aljazeera.com/programmes/inside-story/2012/10/201210236265712261.html). I was staggered to learn from data compiled by The OU's Media Relations unit that my interviews and quotes during the Eyjafjallajökull ash crisis

Figure 9 Demonstrating subduction by hand during a Sky News interview.

Figure10 S186 live on CNN. The Teach Yourself Volcanoes, Earthquakes and Tsunamis *book represents Sumatra, and the two copies of the S186 Module text on the right represent the Indian Ocean floor with a strike slip fault. My finger points to the epicentre of the 11 April 2012 earthquake.*

were seen or heard by in excess of 210 million people. Other news events in the period 2010–2012 mean that I have personally drawn The Open University to the attention of more a quarter of a billion people. Some of my colleagues have been active too, so that's a heck of a lot of people who will now be at least subliminally aware of The Open University as centre of geoscience expertise. If only 0.001% of them would sign up as new students, our current financial worries would be cured.

A shorter version of this paper was published in *Teaching Earth Sciences* **37** (2), 12–15, 2012.

Reference

Rothery, D. A. 2010 *Volcanoes, Earthquakes and Tsunamis*. London: Hodder Education (2nd edn), Teach Yourself Series.

Figure 11 ITV Lunchtime News *in my house, in connection with the 21 February 2011 Christchurch earthquake. Beforehand, I placed some books along the windowsill so I look intellectual. Sadly S186 is hidden behind my head, but note the 'Open University' credit in the caption.*

Figure 12 Al Jazeera *22 October 2012, discussing the l'Aquila earthquake trial. I was in London, other panel members were in Copenhagen and Rome, and the host was in Doha. Note my 'job title' (http://www.aljazeera.com/programmes/insidestory/2012/10/201210236265712261.html).*

Book review

Selden, Paul A., and Nudds, John R. 2012 *Evolution of Fossil Ecosystems* (2nd edn). London: Manson Publishing (ISBN 987-1-84076-160-3; paperback, 288pp; £29.95)

Since the original publication of this book in 2004 (see Jane Clarke's review in *OUGSJ* **27** (1) 2006, page 22), the authors have expanded its contents substantially. The original volume was 160pp — at 288pp this second edition is therefore 80% longer than the original. This appears at first sight to be a huge extension of the book. However, its greater length is partly owing to a larger print-font size. Nevertheless, everything has been expanded and there has also been much reorganisation within the book.

As described in the original review, the title *is* a slight misnomer: the book is about fossil ecosystems, but *by way of* their interpretation and reconstruction from fossil Lagerstätten (situations of fossilisation in which the deposits contain far more complete ecological assemblages than are usually found).

There are six new chapters / Lagerstätten sites or formations. The Index has been expanded from 6pp to 9pp. 'Further reading', as arranged in the first edition at the ends of each chapter, is now included as a full list of References in 12pp preceding the Index. Instead of an Appendix listing museums and site visits at the end of the book, the second edition gives these data at the end of each chapter.

Each chapter of the original has been updated according to further research between 2004 and 2012. The illustrations in the original chapters describing 14 Lagerstätten remain mostly the same, although with some rearrangement and re-sizing. There are also additions to some of the original illustrations and, of course, numerous new illustrations in the six new Lagerstätten chapters.

The organisation of the data on each Lagerstätten is by and large the same as in the first edition: First there is a general introduction describing geological time scales, how Lagerstätten are formed and how the book is organised. There then follow 20 chapters describing each Lagerstätte, following the same format: its evolutionary position and significance; its background sedimentology, stratigraphy and palaeoenvironment; next a description of its biota and palaeoecology, and a comparison to other Lagerstätten; and finally, a list and description of museums where material from the Lagerstätte can be seen and suggestions for visiting the site itself.

The original volume described all the most well-known Lagerstätten [chapter numbers as in this second edition: [1] Ediacara (north of Adelaide, Australia), [2] The Burgess Shale (south-eastern, British Columbia, western Canada), [4] The Soom Shale (north-east of Cape Town, South Africa), [6] The Hunsrück Slate (west of Koblenz, Germany), [7] The Rhynie Chert (north-west of Aberdeen, Scotland), [8] Mazon Creek (in the coal mines of northern Illinois, USA), [10] Grès à Voltzia (around Saverne in north-eastern France), [11] The Holtzmaden Shale (south-east of Stuttgart in the Schwäbische Alb, Germany), [12] The Morrison Formation (major outcrops in the Rocky Mountains of Wyoming, Utah and Colorado, USA), [13] The Solnhofen Limestone (north of the Danube and Ingolstadt, north of Stuttgart, Germany), [16] The Santana and Crato Formations (west of Recife, Brazil), [17] Grube Messel (south of Frankfurt am Main, near Darmstadt, Germany), [19] Baltic Amber (in deposits scattered across the northern European Baltic coastline and East Anglia, UK), and [20] Rancho La Brea (Los Angeles, California, USA),

The additional Lagerstätten described in this second edition are: [3] Chengjang (among and around Lakes Dianchi, Yangzong and Fuxian in south China, near the Vietnam border), [5] The Hertfordshire Nodules (in the middle Silurian rocks of Hertfordshire, England), [9] Karoo (among the Karoo Supergroup stretching across South Africa between Cape Town, Durban and Johannesburg, around Leotho), [14] The Jehol Group (north-east of Beijing, in Liaoning and Hebei, China, and Inner Mongolia), [15] El Montsec and Las Hoyas (in the southern Pyrenees, north-eastern Spain, and west of Cuenca, central-western Spain, respectively), and [18] The White River Group (around and north of Scottsbluff, Nebraska, USA).

The text remains readable and accessible to anyone interested in fossils be they an amateur collector, student or professional, informed geologist. Finally, the book is beautifully produced on high-quality, semi-gloss stock, with a gathered and sewn binding with a textured-card cover wrap.

The second edition is a worthy addition to any palaeontologist's or geologist's bookshelf.

— David M. Jones, BA (Hons) UC Berkeley, MA, PhD UC London, BSc (Hons) Open, OUGS Journal Editor

What are mountains made of? Three decades of Himalayan research

Dr Tom Argles

Senior Lecturer, The Open University

Abstract

In recent years, the Himalaya have fostered a number of fresh theories about how mountains are born and evolve. However, the more we study the Himalaya, the more complexity is revealed. This paper takes the materials of the mountain belt as a starting point for delving into current theories on the processes that have formed and re-shaped the Himalaya (Fig. 1).

Figure 1 View of Kangchenjunga from Darjeeling, north-east India (photograph by Tom Argles).

Introduction

Finding out what mountains are made of may seem a simplistic approach, but in fact that process of discovery opens up all sorts of stories on their past history, and provides insights into how the wider world works.

In this paper, I embark on a sort of field traverse through the Himalaya, from the green foothills up to the snowy peaks, and on to the dry Tibetan Plateau (Fig. 2). On the way, we'll look at work that my colleagues and students have done over the past 15 years or so.

At this point, I should mention my colleagues — or they'll come after me with guns (Fig. 3, *overleaf*)! But much of the data and some of the images in this talk derive from my colleagues' work as well as my own.

Along the arc of the Himalaya, the broad tectonic divisions are remarkably continuous, so any traverse through them is quite similar. Three main units — the Tethyan Sedimentary Series (TSS), the Greater Himalayan Series (GHS) and the Lesser Himalayan Series (LHS) — are separated by major faults along the whole mountain belt (Fig. 4, *overleaf*).

OU research on the Tibetan plateau

Some of the earliest OU research in the Himalaya-Tibet system comprised the 1985 Tibet Geotraverse, involving Professor Robert Shackleton, Nigel Harris, and Julian Pearce (now Cardiff), among other geological luminaries. This ambitious, three-month excursion conducted structural, tectonic, igneous and metamorphic studies across Tibet from Lhasa to Golmud. The relatively low relief of Tibet makes it no less difficult to work in! The geotraverse investigated sediments from the Tethyan Ocean, fragments of ophiolite along sutures running across Tibet, as well as both plutonic and volcanic products of the Gangdese continental arc.

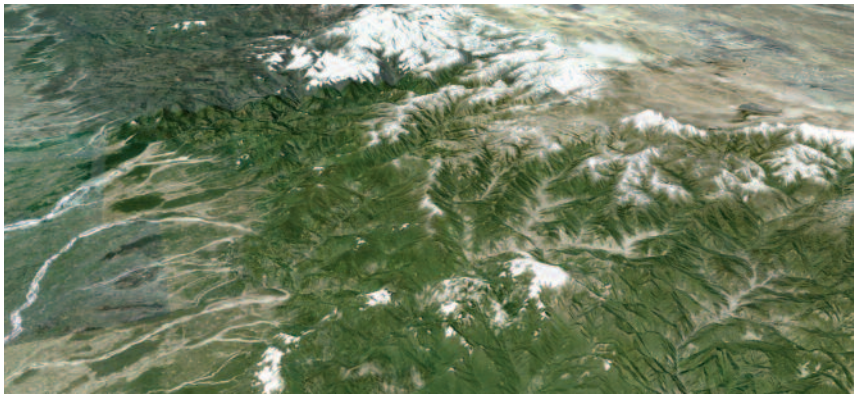

Figure 2 Oblique view from the Gangetic Plain (left) across the Himalaya to the arid Tibetan plateau (top right) (courtesy of Google Earth).

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Figure 3 Joe DiPietro (left) and acquaintances, north-west Pakistan.

Almost 20 years later, a study by Bob Spicer and others combined fossil leaf morphology data with Ar–Ar dating of sanidine feldspar in volcanic tuffs to reveal that southern Tibet has been at its present elevation for at least 15 million years (Fig. 5). This study was the highlight of a fertile period of Tibetan research by The OU, with PhD students Helen Williams and Jess King both publishing original papers using geochemistry to probe melting processes in the deep crust and mantle beneath the plateau. Helen discovered two groups of shoshonites, ultrapotassic lavas formed from mantle melting: one in the north caused by thinning of the sub-continental lithospheric mantle, the other in the south resulting from break-off of a subducted crustal slab. Jess King investigated 14Ma dacite dykes south of the suture that carry a mantle melt signature (from either slab break-off or delamination), along with Sr–Nd isotopic signs of Asian crust in channel flow.

Jess also defined two generations of granite: one formed early (*c.* 25Ma), reflecting initial wet melts of Indian crust indicating mid-crustal channel flow; and a later porphyritic suite (14–9Ma) representing post-tectonic dry melts of rapidly exhumed GHS schists.

Throughout this talk, I will scatter short intermissions on the theme of experiences to avoid during Himalayan research, in the form of 'Try not to…' lists.

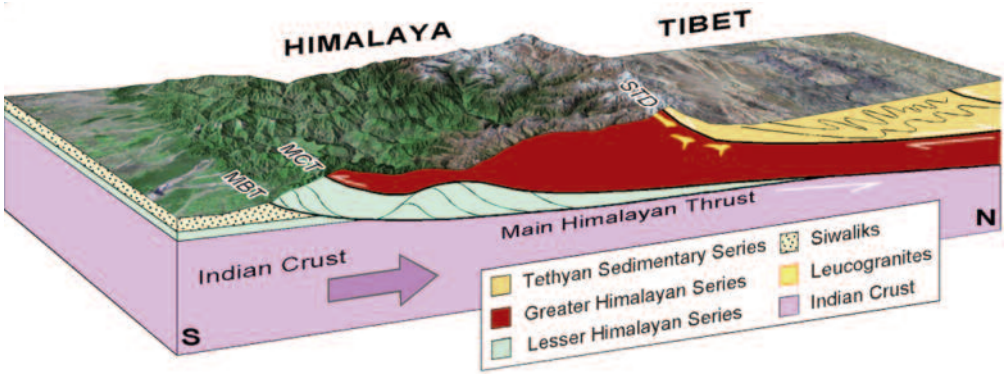
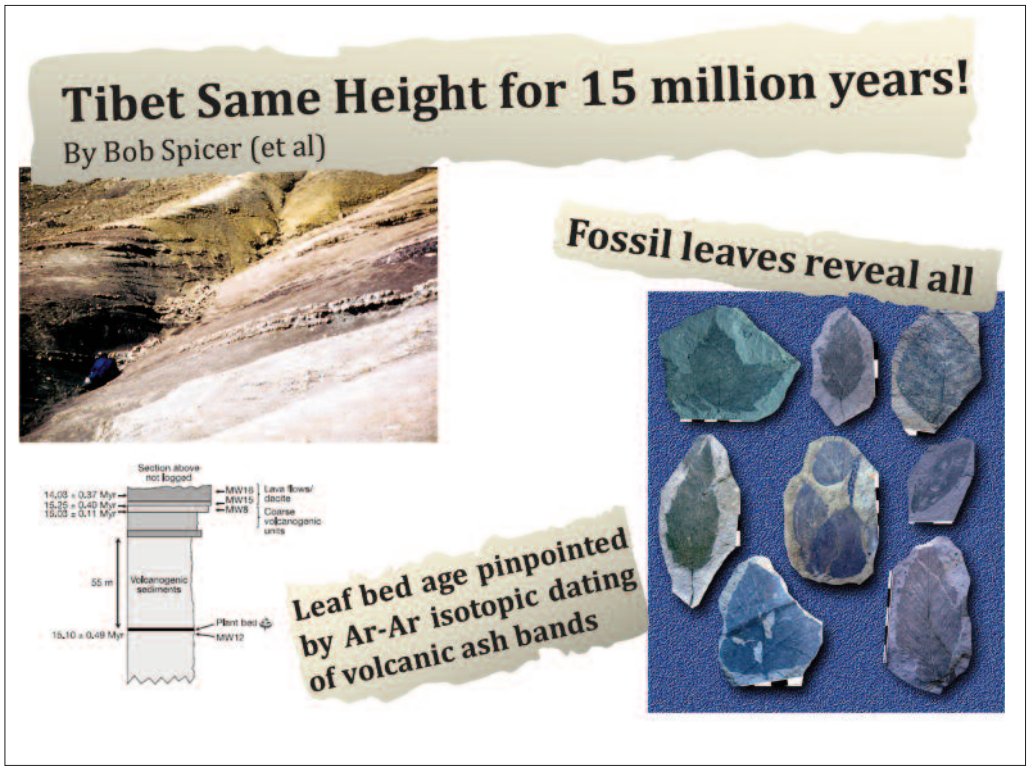


Figure 4 Simple cross-section through a typical traverse across the Himalaya.

Figure 5 Montage of the Spicer et al. *(2003) Nature paper that established the longevity of uplift in southern Tibet.*


Tibet Same Height for 15 million years!
By Bob Spicer (et al)
Fossil leaves reveal all
Leaf bed age pinpointed by Ar-Ar isotopic dating of volcanic ash bands

Try not to… High Plateau

- get arrested/interrogated by the PLA;
- contract Altitude Sickness so acute that you have to be flown out of the country;
- throw a hammer at your supervisor;
- drink the Chinese brandy;
- order champagne at a tourist hotel in Lhasa;
- get propositioned by the local village girls.

High Peaks: Himalayan leucogranites

These rocks are perhaps the most studied in the Himalaya. Mainly Miocene in age, the majority formed *c.* 20Ma, as anatectic melts of the thickened crust of the Indian margin. Many contain tourmaline and/or garnet. Current dating suggests that these leucogranites may tend to be younger in the eastern Himalaya than in the central or western orogen.

The granites are very useful for putting dates on episodes of Himalayan history, as many cross-cut earlier, deformed leucogranites and gneisses (Figs 6 and 7, *opposite*). Many form large plutons at shallow crustal levels, forming due to decompression melting during rapid exhumation of the middle crustal rocks of the GHS.

Figure 6 Undeformed tourmaline leucogranite, south Tibet.

Most of the granites only form once mid-crustal channel flow is well under way.

However, some minor early melts may prove more significant, as they may have provided the initial viscosity decrease required to trigger channel flow in the first place. Only a few volume percent of melt in the middle crust is thought to allow channel flow to develop (Fig. 8, *overleaf*).

A number of OU projects have investigated the causes of melting for various leucogranites along the Himalaya, including early, Oligocene granites as well as the 'typical' Miocene type.

John Massey and Simon Inger, along with Nigel Harris, used geochemical modeling (Rb, Sr and Nd) to prove that the Miocene leucogranites were formed by vapour-absent, muscovite-dehydration melting during decompression of fertile schists. A later study by Christophe Prince, Derek Vance and Nigel Harris discovered older leucogranites (35Ma), formed by hydrous melting on the prograde path, that could represent the original trigger of mid-crustal channel flow (Fig. 9, *overleaf*).

Try not to… High Peaks

- fall off;
- annoy the locals with the AK47s;
- get caught drying cannabis on your tent;
- drink the Hunza brandy;
- get four punctures in two days on the *same* jeep;
- contract Giardia (too often);
- have too many Bhutanese hot stone baths.

Heart of the mountains: Greater Himalaya

The metamorphic core of the orogeny is characterised by high-grade rocks, rapidly exhumed from the middle crust during the Miocene. It's a dynamic landscape that presents many challenges for fieldwork, not least the roads — which are constantly being damaged and renewed by a permanent force of engineers. In India, these guys are the Border Roads Organization (BRO), a division of the army (Fig. 10, *page 37*).

When I first arrived at The OU in the late 1990s, we were investigating the prograde heating history of the GHS, unlike many other Himalayan researchers who were focusing on the rapid exhumation and melting story. Our group, which included Gavin Foster, Christophe Prince, Derek Vance and myself, began painstakingly determining when garnets first grew in Himalayan rocks, using Sm–Nd isotopic geochronology.

Our results from Pakistan and north-west India indicated that garnets grew during burial and heating of the Indian crust from *c.* 44Ma to *c.* 30Ma, quite a protracted period. However, one garnet from north-west India gave an age of 535Ma — evidently a relic of an earlier metamorphic event, completely unrelated to the recent India–Asia collision, which had survived the Himalayan orogeny to confuse present-day researchers! Subsequently, Jen Chambers dated garnets in north-west India of both Himalayan (41Ma) and Early Palaeozoic (470Ma) ages,

Figure 7 Discordant Miocene leucogranite, north-west India.

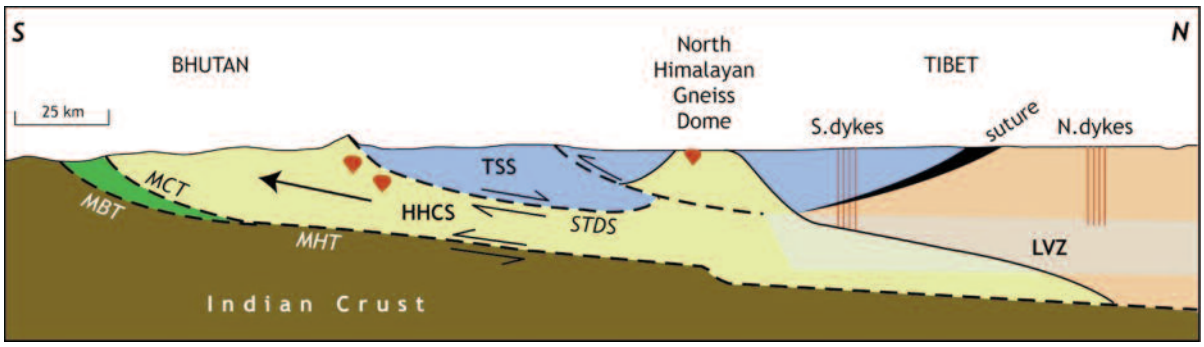


Figure 8 Schematic diagram of channel flow beneath the Himalayan-Tibet system. HHCS = GHS. Focussed erosion at the mountain front causes rapid exhumation of the mid-crustal channel bounded by the MCT/MHT and the STDS.

confirming the existence of an earlier orogenic event in the Himalayan rocks (Figs 11, *opposite*, and 12, *page 38*).

Try not to… Heart of the mountains

- get angry when a rock wrecks your tent during blasting;
- attempt to camp in a truck stop;
- run out of gas (and popcorn!);
- get your jeep stuck in a river;
- drink the water;
- lose too many of your horses.

Foothills: Lesser Himalaya

The Lesser Himalaya is characterised by ancient rocks that underlie the Main Central Thrust (MCT). This series of rocks represents the passive margin of India for *c.* 2 billion years, and includes mainly low-grade metasediments, deformed granites, and minor mafic rocks. However, in some transects there are LHS rocks that are much higher grade — schists and gneisses — some of which have even undergone partial melting. These rocks can be difficult to distinguish in the field from similar lithologies in the GHS, overlying the LHS along the Main Central Thrust.

Over the last 15 years, researchers at The OU have played an isotopic game of 'spot the difference' to discriminate these two tectonic units. A combination of Nd–Sr bulk-rock data and detrital zircon U–Pb dating has helped re-draw the map of the Himalaya, challenging our understanding of the tectonic architecture in several transects, and in many cases revising the location of the MCT altogether (Fig. 13, *page 38*).

As well as revising Himalayan maps, these studies have provided valuable insights into the palaeogeographic evolution of the Himalayan region, including the causes of the marked isotopic shift between LHS (ancient detritus) and GHS (mixed detrital source) metasediments.

Try not to… Foothills

- accept an invitation to a Hindu wedding;
- aggravate the jeep driver;
- attempt to buy gin in Darjeeling;
- drive into Guwahati;
- get propositioned by the local girls;
- annoy the leeches;
- think about the toilet facilities.

Figure 9 Montage of results from OU research papers on the High Himalayan leucogranites.

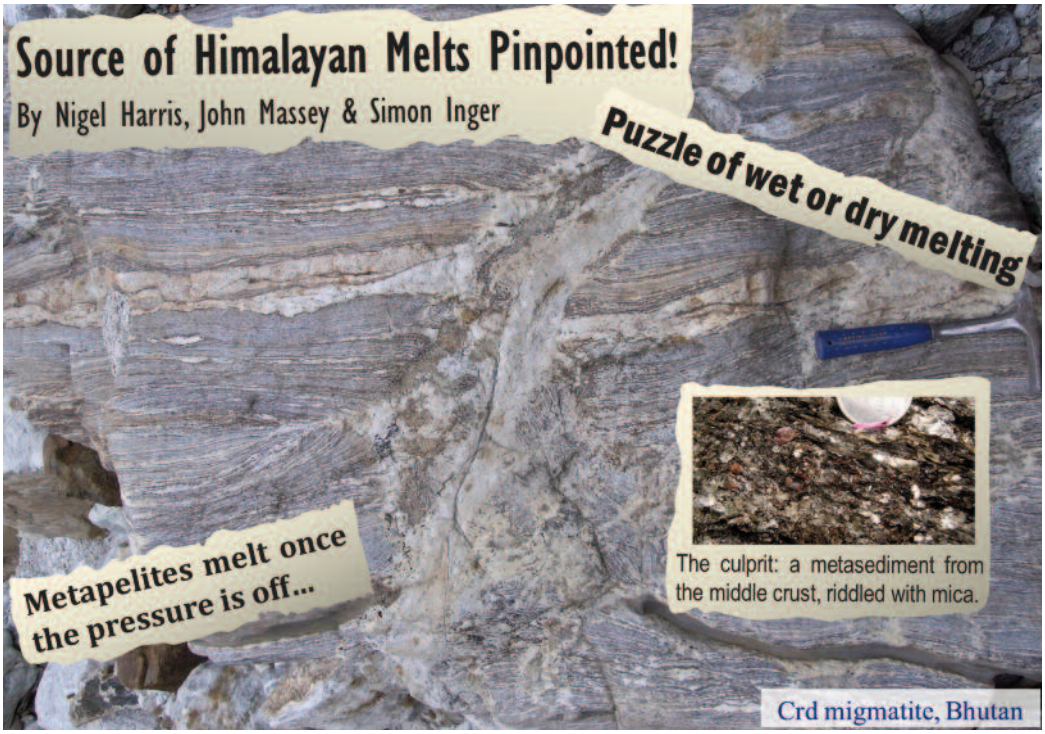

Source of Himalayan Melts Pinpointed!
By Nigel Harris, John Massey & Simon Inger
Puzzle of wet or dry melting
Metapelites melt once the pressure is off...
The culprit: a metasediment from the middle crust, riddled with mica.
Crd migmatite, Bhutan

Figure 10 Roads in disrepair: (left) Sutlej Valley, north-west India, May 2001; (right) Gangtok to Siliguri, Sikkim, September 2010.

Mountain front: Siwaliks

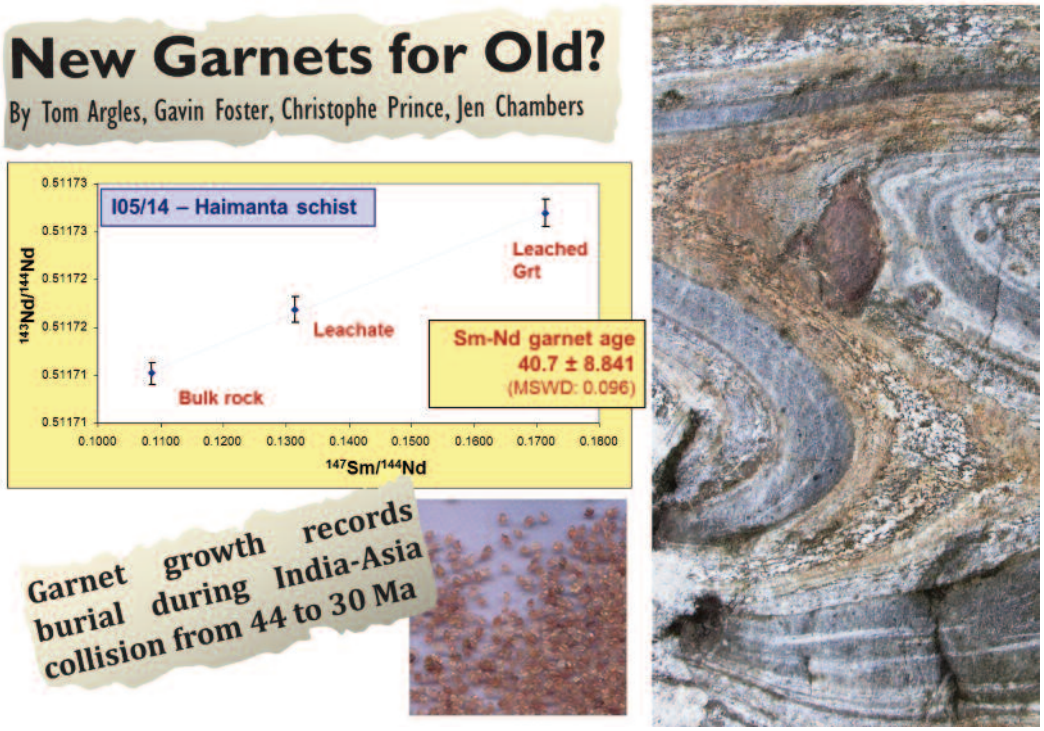
On the southern edge of the Himalaya, the weight of the mountains depresses the crust, forming a broad trough called a 'foreland basin'. But there is a very abrupt transition from basin to foothills, where the first thrust is encountered. This basin is a 'mountain graveyard' — filled with the ground-down bones of the Himalaya, sedimentary detritus in the form of sandstones, siltstones and conglomerates, carved out of the heart of the mountain chain by some of the world's greatest rivers and dumped on the Gangetic Plain (Fig. 14, *page 39*).

In the past decade, OU researchers have dabbled in studies on the foreland basin, mainly analysing river water chemistry to try and quantify the flux of elements and isotopes from the plateau and mountains through the plains to the ocean. Variations in ocean chemistry over time have been considered indicators of climate change, but sudden influxes of material from rapidly eroding mountain belts can perturb that signal; these effects must be understood to de-convolve the true climate signal. Recent projects have even involved Nigel Harris working in caves.

So, we've come to the end of our notional field traverse through the mountain belt, and edited highlights of the last three decades or so of OU research in the Himalaya and Tibet. As a final, blatant plug, you can catch up with some of our recent (and older) work online on the HiT Group website at The OU (*see* below), or alternatively on our YouTube channel (Fig. 15, *page 39*).

http://www.open.ac.uk/research-groups/himalaya-tibet/
http://www.youtube.com/userHiTGroupOU

Figure 11 Montage of results from OU research papers on garnets from the Greater Himalayan Series.



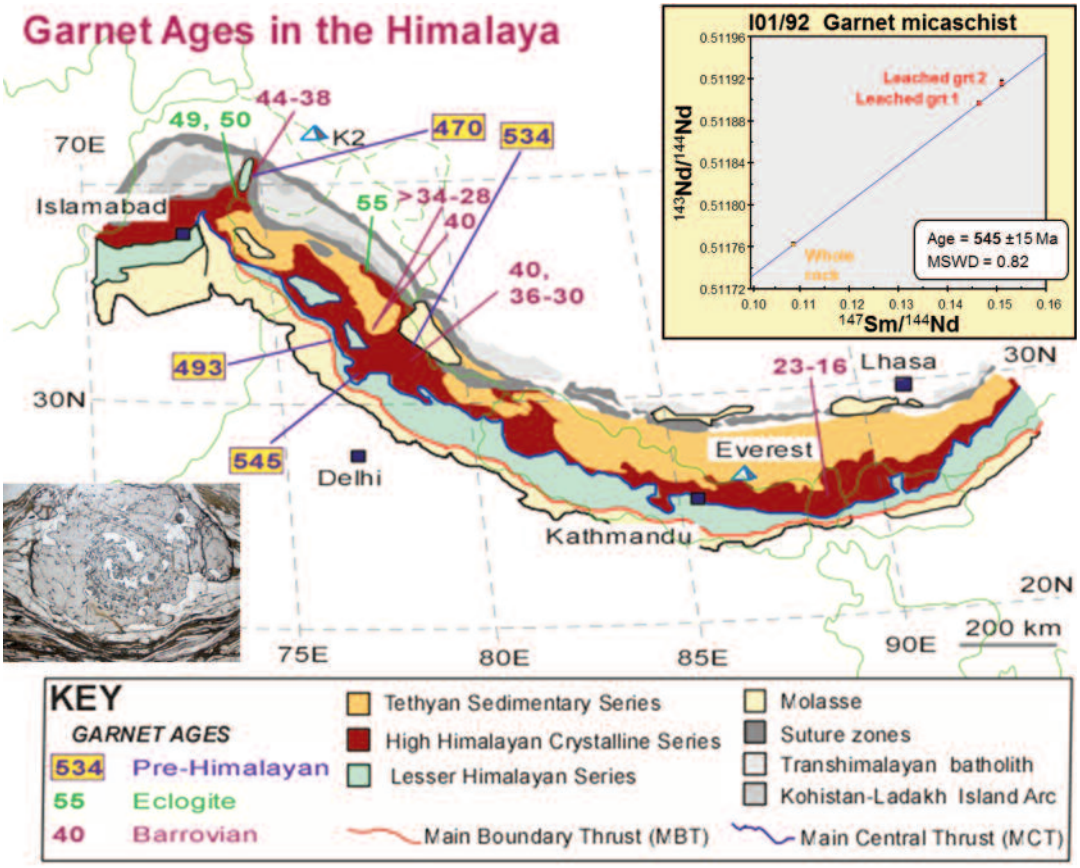


Figure 12 Compilation of garnet ages determined in the Himalaya, mostly by OU researchers.

Figure 13 Montage of OU 'isotopic fingerprinting' research along the whole Himalaya.

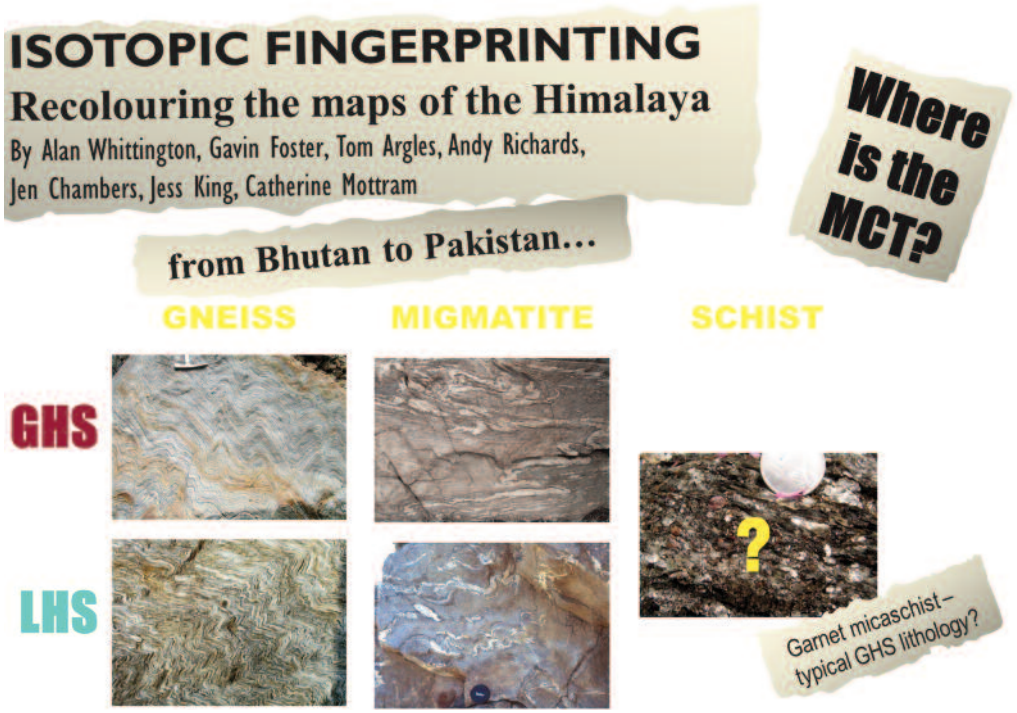


Figure 14 Part of the Brahmaputra River in West Bengal, loaded with sediment eroded from Tibet and the Himalaya.

Sources and further reading

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Figure 15 The OU Himalaya-Tibet Research Group website (left) and YouTube site (right) – please pay us a visit!

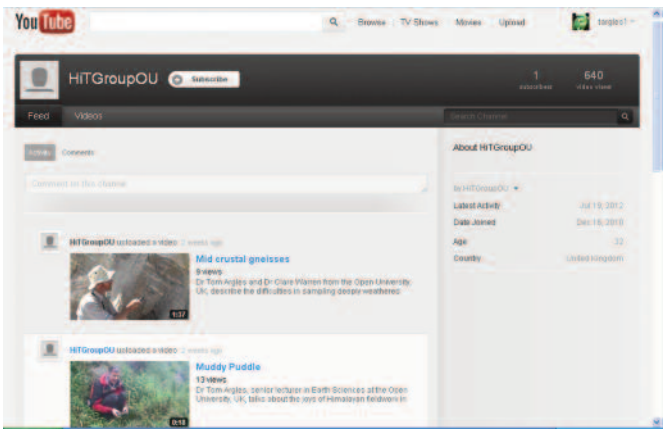

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Figure 16 View of the natural habitat of the rare Ibisbill and of the author (Rodophu, Bhutan).